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Numbers 447 and 448

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13 December 2013

Dear Journal subscriber/Journal exchange partner,

Unfortunately, due to a technical problem with typesetting the *Journal and Proceedings of the Royal Society of New South Wales* (vol 146 part 1, nos 447, 448), some images were not present in the printed copy of the Journal that you would have received about three weeks ago.

Please find attached errata sheets to be inserted in your copy of the Journal.

We regret any inconvenience that this may cause.

Yours sincerely,
The Royal Society of New South Wales

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THE ROYAL SOCIETY OF NEW SOUTH WALES

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JOURNAL AND PROCEEDINGS OF THE ROYAL SOCIETY OF NEW SOUTH WALES
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Five expert working groups were established to review the roadmap, with four of these aligned with the National Research Priorities (Environmentally Sustainable Australia, Promoting and Maintaining Good Health, Frontier Technologies, Safeguarding Australia). In addition to the fifth expert working group covering the Humanities, Arts and the Social Sciences, an ICT Strategy Group identified and synthesised current and future ICT research infrastructure requirements.

The characterisation capability became constituted as the Characterisation Council (DIISR 2008, DIISR 2010) which consists of the National Imaging Facility (NIF), the Australian Microscopy and Microanalysis Research Facility (AMMRF), the National Deuteration Facility (NDF), the Australian Synchrotron and the Australian Synchrotron Research Program.

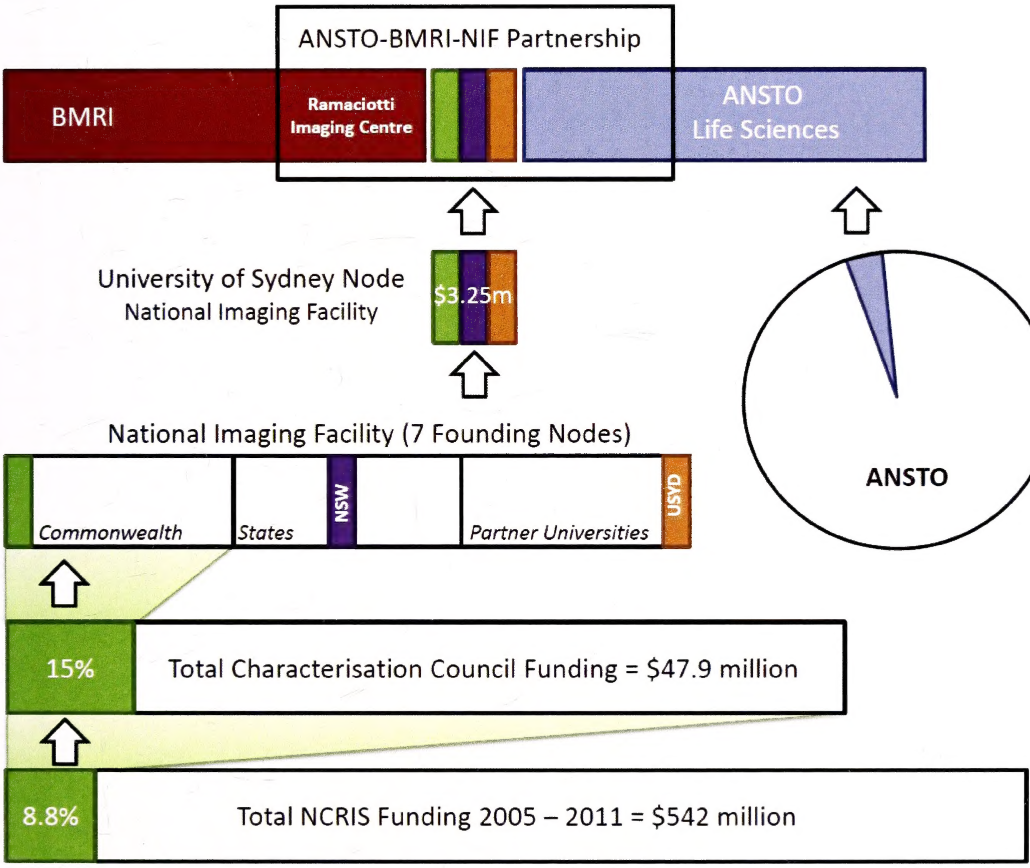

Figure 1: This figure shows how funding and in-kind contributions to new research infrastructure from Commonwealth, State, institutional and philanthropic sources created a nested partnership embedded in a larger network. The main philanthropic contribution towards the molecular imaging infrastructure has been the seed funding from the Clive and Vera Ramaciotti Foundation for a state-of-the-art imaging laboratory, the Ramaciotti Centre for Imaging at the BMRI.

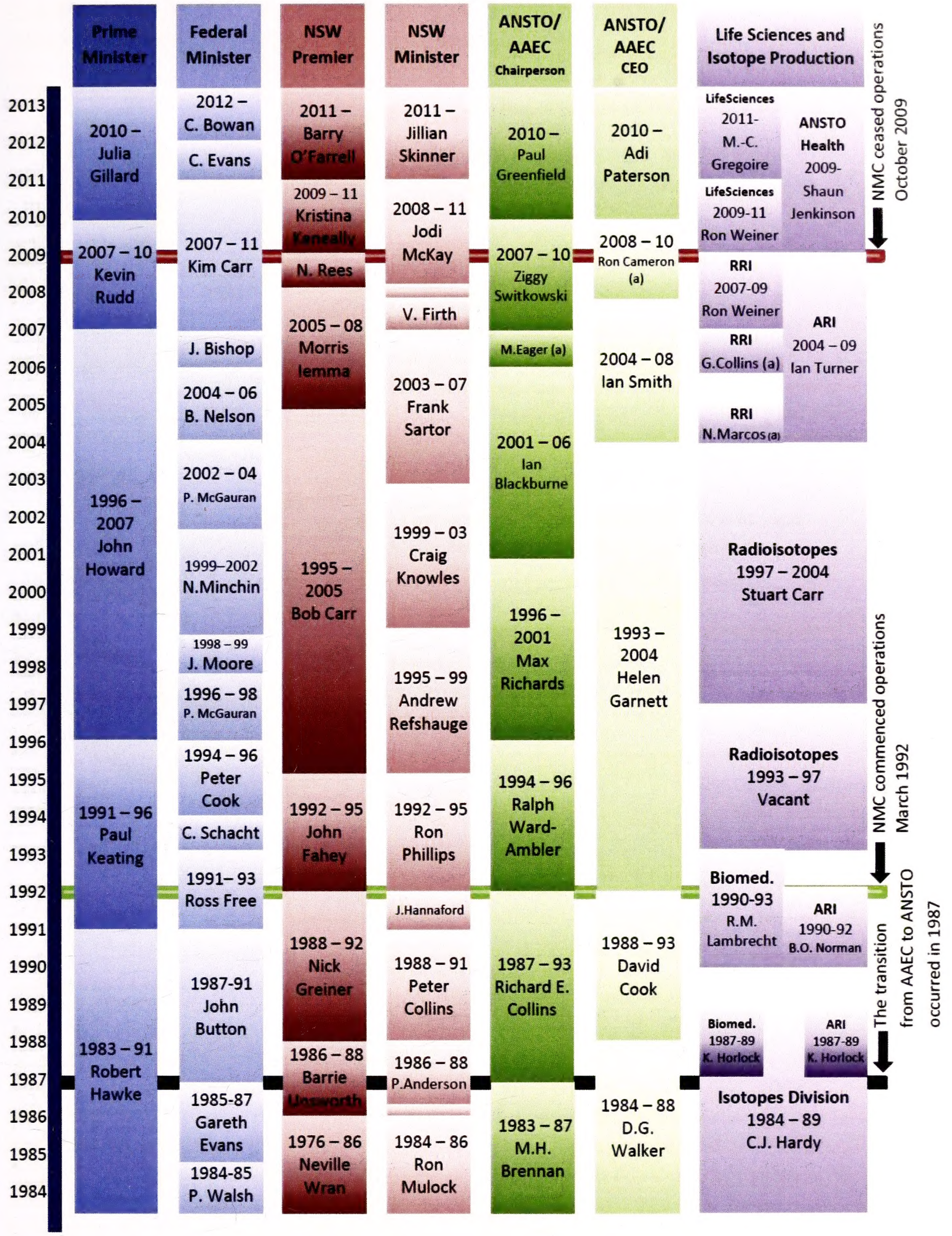

Figure 3: Federal, State and ANSTO leadership from 1984 until present. The development of the NMC and subsequently the national imaging facility cyclotron occurred against a backdrop of significant changes. It illustrates the degree to which the development of a large-scale infrastructure relies on persistent support from successive governments and stability in organisational priorities.

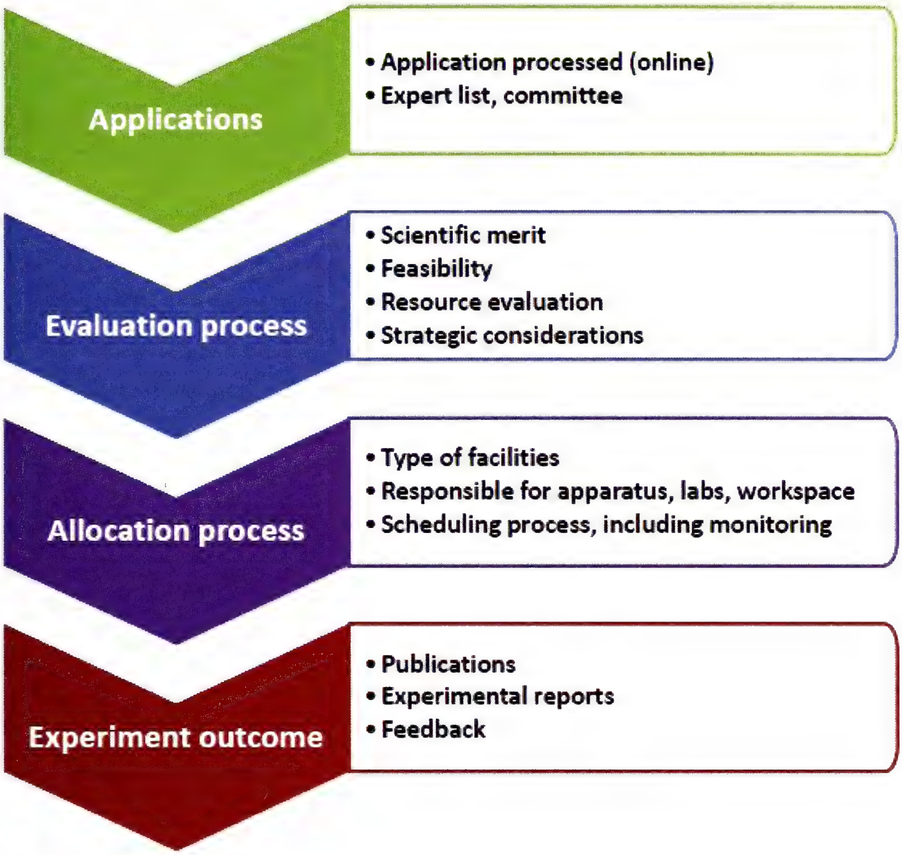

Figure 5: Schematic access scheme for use of the facilities: Applications are reviewed by experts and if successful the experiments are scheduled coordinating the experimental requirements with availability of facilities and people. Experimental outcomes are captured in the academic literature or in annual reports.

Although there are different access routes, all partners have incorporated a review procedure by experts who evaluate the proposals on scientific merit and feasibility, resource availability as well as strategic considerations. The allocation process includes monitoring throughout the project.

The ANSTO-BMRI-NIF platform provides access to a dedicated research cyclotron and radiochemistry capability that includes the development of either already validated or new radiopharmaceuticals at the ANSTO Camperdown facility that, in the case of short-lived radioisotopes, are deployed to the nearby imaging laboratories at the BMRI. These laboratories are equipped with multi-modality preclinical and clinical scanners that use the molecular probes to measure specific biological functions related to disease. In addition, a high performance computing platform provides advanced imaging analysis and modelling.

the training and educational aspects of the partnership.

Education and training

Education and training, is generally provided in the context of defined disciplines. However, molecular imaging is interdisciplinary. It has been pointed out (Bammer 2013) that in order to strengthen interdisciplinary practice and capacity, a re-think and co-ordinated activity would be required. This would include developing agreed frameworks, compiling and classifying what we already know and turning isolated individuals and groups into co-ordinated networks of peers and potentially new disciplines.

Molecular imaging is strongly interdisciplinary with multiple overlapping engagements, as illustrated in Figure 6. Thus, skill acquisition in molecular imaging is complex and needs to be supported by a range of different educational providers, including vocational and tertiary education institutions as well as professional associations and interest groups.

In molecular imaging, we see thus "a team composed of members of a number of different professions cooperating across

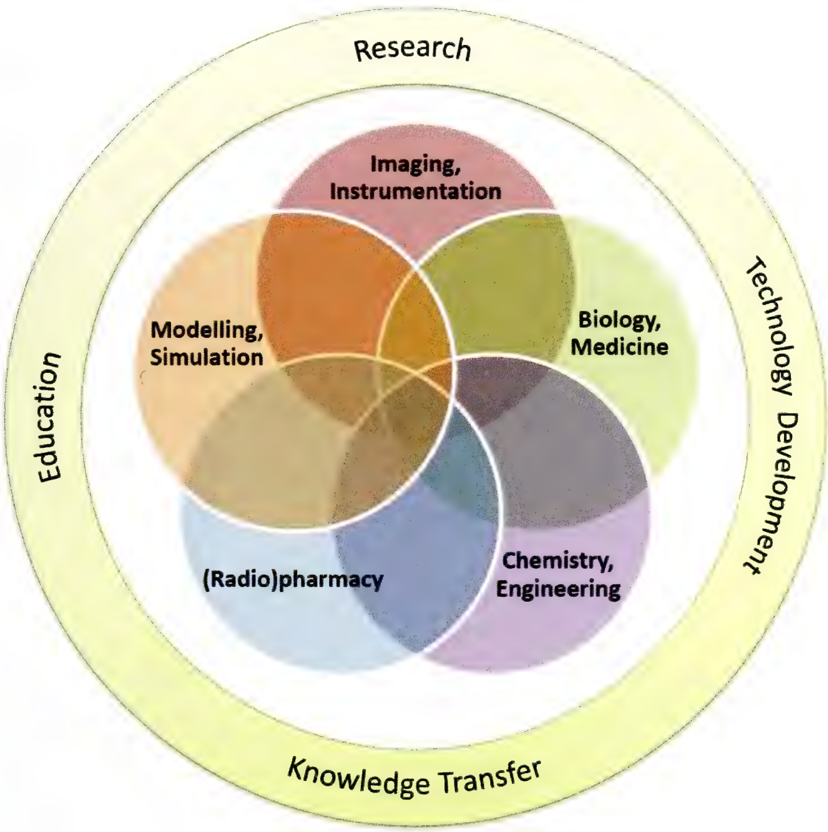

Figure 6: The scheme illustrates the interdisciplinarity in molecular imaging and the broad set of skills that education and training needs to provide (modified from (Grimm 2013) and (BME 2013)).

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Editorial

Volume 146–1 of the *Journal and Proceedings* goes to press just after the Society has held its annual Forum, this year at Sydney's Powerhouse Museum. With education reforms very much a part of the current political agenda the subject matter chosen was certainly topical: "Maths and science education in Australia – is there a crisis?" While there is no doubt there are many issues of consequence around questions of levels of scientific literacy in Australia – such as how society responds to the issue of climate change – whether that is the result of a crisis in our education system, or perhaps reflects a cultural divide in the community, is a matter of debate. What is clear, however, is that there is a crisis in our ability to teach science in our schools – in particular maths and physics – with large numbers of school teachers qualified in these areas fast approaching retirement age, and without a similarly qualified cohort of younger teachers ready to take their place.

As a university teacher of physics who sees the output from the school science system – over 10,000 students have now passed through my own classes – the consequences of limited preparation for the demands of problem solving that undergraduate physics students are subjected to are clear to me. At UNSW, while around 2,000 students pass through the doors of our first year physics program, by the time honours level is reached we rarely have more than 10 remaining. Now, while of course many are instead studying challenging courses in other fields such as engineering, this is a mere 0.5% uptake from those who were sufficiently qualified to start a university-level physics course in the first place. While the best students are brilliant, too many find themselves ill-equipped to develop their skills in critical analysis and quantitative reasoning which are among the essentials of a science education.

Ask any person who excels in a scientific field of endeavour why they got started in that field and invariably the response is because of an inspirational teacher at school. The multiplier effect to society of one great teacher is immeasurable. One such teacher might be able to inspire tens to hundreds through the span of their own career to take up and tackle the challenges of university-level science. This is a mighty contribution towards equipping the next generation for dealing with the ever increasingly technologically-dependent world that we all inhabit.

So how do we inspire a new generation of science teachers into our schools? This is one of the big challenges we face as a society and there appear to be no easy solutions. There are impediments we might consider removing, however. The best science teachers will invariably come from the cohort who have taken science the furthest at university, yet there are real barriers to their employment in the school system. The lack of a formal teaching qualification should one decide to turn ones endeavours to teaching from another field while in mid-career is one such barrier. Might there be means of providing teacher training while on the job, so as to avoid the need to completely stop one career to re-train for another? This is essentially the way teaching is learnt at university – on the job experience. While it might result in some rough edges along the way, there is nothing like jumping in at the deep end to learn how

to swim. The first essential to teach a subject is to know that subject. This cannot be learnt on the run. Unfortunately the lack of maths and physics teachers at many schools has the consequence that these subjects are often taught by life science teachers who found it an effort to get through their first year university physics course and went no further with it. No matter how motivated and dedicated they are, such a teacher is always going to struggle to instill the fundamentals of physics in a student.

Anyone knowledgeable in physics is also literate in mathematics, and vice-versa. The key concept of problem solving in each field is the same. If you can teach in one of these fields you can also teach in the other. I know, as that was my own career path, having trained in mathematics and yet now earning my living by teaching physics, without having received a formal training in it (or in teaching, for that matter). Yet there are barriers within many schools against such cross-discipline teaching.

Another matter of contention is whether to incentivise the teaching profession through differential salary scales. In the university system there now may be a factor three between the highest and lowest paid academics, the result of a clear career progression path together with performance-based incentive schemes. While a meritocracy in salary might be an ideal we should aspire too, one can question whether it is also presenting a barrier to bringing in the best science teachers to the school system. While the research-based metrics used in universities as part of their performance appraisal systems might not be applicable in the school system, perhaps a simpler criteria of qualifications and years of experience in the requisite fields of need might be used instead when determining remuneration levels? For instance, a relevant doctorate could attract a higher starting salary?

This issue of the *Journal* brings in three research papers, two invited discourses and two thesis abstracts. The subject matter covered is broad, from the causes of the Global Financial Crisis, to the medical cyclotron at Sydney University, to the career of the new Director of the Australian Astronomical Observatory (Warrick Couch). In a new direction for the *Journal* the GFC article contains a timeline as online-only material, a feature we hope to be able to expand on in the future to allow the presentation of additional material, too extensive for the print edition of the *Journal*. Of the two invited discourses, we hear from John Dickenson on the invention of the pendulum weight shift hang glider, a fascinating story that emerges from the sport of water skiing. Finally, Society President Donald Hector discusses the humanist paradox, elements of which are strong in the discussion of scientific literacy, education and cultural divides in society, as espoused in the Society's recent Forum.

Michael Burton
Hon. Secretary (Editorial)
June 15, 2013

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Learning Lessons? The Global Financial Crisis five years on

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Abstract

The main contribution of this paper is a Timeline of the Global Financial Crisis (GFC) from 1720 to 2013. It is accompanied by analysis in which I distinguish between the sufficient conditions for the Global Financial Crisis (GFC) (the conjunction of many things which occurred before the GFC, which were correlated with the GFC, and perhaps influenced it) and the necessary conditions for the GFC (those things without which the GFC would not have occurred). Is it possible to distinguish between elements of these two sets? Avoiding unnecessary regulation in the future, while insuring against a repetition, would suggest that one must strive to do so, for policy reasons, as well as for understanding the paths that led to the GFC. I conclude that three conditions were necessary for the financial crisis in the U.S., which, in turn, resulted in the GFC. All were failures of regulation.

Introduction

In its Leader of October 13, 2008, the *Financial Times* (*FT*) characterized the western world's banking system as suffering "the equivalent of a cardiac arrest". The collapse of confidence in the system means that "it is now virtually impossible for any institution to finance itself in the markets longer than overnight". This occurred less than a month after Lehman Brothers (LB) collapsed, without bailout. Six months earlier Bear Stearns (BS) had been bailed out after JP Morgan Chase (JPM Chase) had bought it for $10 a share, at the regulator's urging. After LB fell, who would be next? And if LB, who was not at risk? Despite the earlier U.S. government bailouts of the erstwhile government mortgage originators (and still seen as government-sponsored enterprises, or GSEs), the Federal National Mortgage Association (Fannie Mae) and the Federal Home Loan Mortgage Corporation (Freddie Mac), and the later bailout of the world's largest insurer, American International Group (AIG), everything changed with the demise of LB.

The FT was describing the freezing of the interbank credit market. After LB's fall, so-called counterparty risk was seen as prohibitive to prospective lenders, at any price. This was revealed in the TED spread, the difference between the cost of interbank lending, the London Inter Bank Offered Rate, or Libor, on three-month loans in U.S. dollars, and the closest instrument to risk-free: three-month U.S. government bonds. In normal times the TED spread is between 10 and 20 basis points (bp), or 0.10 and 0.20 percent per annum, but on October 10, the TED spread reached 465 bp, when a lender could be found. In November, 2008, it had fallen back to below 200 bp.

I sit in a coffee shop that sports the sign "We are cash only, sorry for the inconvenience." I'm sure this is to avoid the hassle of credit cards, but such signs were massing off-stage in mid-October, 2008. How so? Imagine that banks refused to honour other banks' credit card debts. Then cash would soon become king for retail purchases. But what of letters of credit, used in international trade? What of other bank-backed credit instruments? And cash (fiat money) also relies on trust and confidence — of government. And when the government can't be trusted? This can result in catastrophic inflation, or devaluation, or both. And when there is a shared currency across countries, things can get very messy.

The U.S., U.K., European and Australian governments understood the abyss that faced the world economy, and the U.K. action at supporting its ailing banks and guaranteeing interbank lending was soon imitated elsewhere. The 2008 financial crisis, although severe, has not been catastrophic. Millions, however, saw the value of their assets on the stock market dwindle, and millions more lost their houses and their savings. Alan Greenspan (2010) called it the once-in-a-hundred-years event.

A related issue is the extent to which the action of governments in 2008 ameliorated the macro-economic consequences of the GFC, which might now have led people to underestimate the perils faced in October 2008, and so to underestimate what might be desirable to avoid future credit crises, perhaps not so distant.

The crisis was triggered by the bursting of the U.S. housing bubble,[1] and U.S. housing prices tumbled as the crisis led to further sales to improve liquidity. But, as we argue, other events were necessary for the bursting bubble to result in the crisis. Many also lost their jobs, at first in the finance industry, but later increasingly in the real economy.

But shed no tears for the shareholders or top managers of the U.S. finance companies. A very good description of the process that resulted in the subprime (SP) mortgage meltdown is a piece by Lewis (2008). Lewis gives a very insightful timeline of the unfolding of the crisis by focusing on a small group of people who were on Wall Street.[2] Johnson (2009, 2010) argues that since none of the bankers sought personal bankruptcy, and the banks avoided harsh measures in the 2010 U.S. financial reform act, it constitutes a "quiet coup."

There are three kinds of indicators of the progress of the GFC: prices and interest rates in financial markets, the performance of firms in the finance industry (at least at first), and then government responses to the growing crisis. As the events of 2008 flashed by, I began to put together my own Timeline of the crisis, from the far past to the present. I continue to add items, both current and past, as they are revealed. I have used many on-line resources and articles such as Brunnermeier (2009).

Necessary conditions for the GFC

In June, 2009, almost two years after the first market signs of the GFC and following my editorials in two issues of the *Australian Journal of Management* (Marks, 2008a, 2008b), and a timeline of the GFC (in the June 2009 issue

1 Even where there is recognition that a bubble exists, it is extremely difficult to forecast exactly when it will burst. That is not our task here: it is to identify the underlying causes of the bubble and the impacts of its bursting.

2 This piece was the inspiration for the Timeline below.

of the *Journal*, with an updated version below), it was time to begin attempting to answer the question of what caused the GFC. This is not simple. Many decisions and actions, by many individuals and organisations, came together to cause the GFC. Even asking whether it would still have happened absent any one of these decisions or actions is difficult to answer since it is counterfactual, and we can't run history again with this single difference in order to answer such questions.

Instead, in the Timeline, I have listed decisions and actions that together accompanied the GFC, as well as market indications of the crisis, and subsequent government actions in attempting to alleviate the crisis. (I will not here engage in the debate of what government policies are appropriate except to say that apparently Richard Nixon was wrong when he claimed in 1971 — almost 40 years ago — that: "We are all Keynesian now". Conservative politicians, both here and abroad, appear to be unaware of the merits of incurring short-term debt to pay for Keynesian stimuli and the virtues of the automatic macro equalisers of the modern economy.)

Looking at the Timeline (which is now much richer than the version I published in Marks 2008b and 2009) – see the online material – I count these significant events:

1. six changes to U.S. legislation from 1977 to 2008;
2. two changes in financial institutions' ownership;
3. a change in corporate governance;
4. several new technologies;
5. several market and extra-market events;
6. three regulatory changes that might have contributed to the financial crisis of 2008, and two changes that were in response to events in 2008; and
7. at least six changes in corporate behaviour.

I have also included several Cassandras — voices warning of danger who were ignored or, worse, shouted down since 1994, but more prevalent in the two years 2007–2009. Accompanying these have been a series of denials, and, more recently, a number of admissions of prior mistakes. Before I discuss these in more detail, I repeat that it must remain a question of individual judgment about which of the earlier actions caused the GFC.

The six legislative changes

The six legislative changes all occurred in the U.S.A. In 1977 U.S. banks were offered incentives to lend to poor people.[3] In 1980, usury controls for U.S. mortgages were lifted, allowing higher interest rates for risky borrowers.[4] In 1988, discrimination in the U.S. mortgage market was outlawed.[5] In 1999, many 66-year-old restrictions on U.S. banks were lifted, and bank regulation was eased.[6] In 2000, self-regulation of derivatives was affirmed, and some (such as the then recently invented Credit Default Swaps, CDSs) were explicitly exempted from state gaming regulations.[7] In 2008, the (new) regulator was given the power to place government-sponsored enterprises (GSEs), such as Fannie Mae and Freddie Mac, into receivership or conservatorship.[8] It is

3 1977 October 12: *The Community Reinvestment Act.*

4 1980 March 31: *The Depository Institutions Deregulation and Monetary Control Act.*

5 1988 September 13: *The Fair Housing Act.*

6 1999 November 12: The Gramm-Leach-Bliley *Financial Services Modernization Act* repeals the Glass-Steagall Act of 1933.

7 2000 December 21: *The Commodities Futures Modernization Act.*

8 2008 July 30: The *Federal Housing Finance Regulatory Reform Act.*

debated whether this last was a cause or an effect of the financial crisis (McLean, 2009).

Since the GFC was triggered by the bursting of the U.S. housing bubble (which, as Greenspan (2010) points out, unlike the 1987 stock-market collapse or the "tech wreck" of the early noughties, was not limited in the extent of its impacts), it is appropriate to focus on U.S. legislation. Both sides of politics saw political advantages in increasing home ownership, which, in itself, need not have led to the housing bubble — other countries, such as Australia, have also encouraged home ownership, without (yet) bursting housing bubbles, and without such consequences in the aftermath of a housing crisis.

Of these legislative changes, with hindsight, the repeal of the 1933 Glass-Steagall Act was the most significant: not the elimination of the geographic limits on bank operations, but rather elimination of the distinction between trading banking and investment banking. Given the disappearance of the investment-bank partnerships (starting with Salomon Brothers in 1981 (see below)), the banks' managers now faced strong incentives to grow. Which they did: the market share of the five largest U.S. banks rose from 8% in 1995 to 36.5% in June 2010.

Of course, after LB the powers that be decided that AIG and the rest were "too big to fail" (TBTF), a policy that has since been repudiated by King (2009) and even Greenspan (2010), and which raises issues of "moral hazard": not only do managers of TBTF institutions take more risks than managers of smaller institutions, the risks they pose to counterparties are lower and so their costs of capital are lower than the costs charged to small institutions. This is a recipe for even greater concentration in future. If there were economies of scale for larger banks, then at least there might be some upside to this growth, but Greenspan (2010) and others argue that there is no evidence of such economies, once banks have grown beyond a relatively small size.

Changes in financial institutions' ownership

The changes in financial firm ownership occurred over 18 years: in 1981 the first of the Wall Street investment banks, Salomon Brothers, previously a private partnership — as were all such investment banks then — sold itself, to become a publicly traded corporation.[9] The other banks followed suit, until the last, Goldman Sachs (GS), went public in 1999. They were now using what was predominantly other people's money. In 1997, the U.K. building society (or thrift), Northern Rock, demutualised to become a bank, the first of several.[10] Ten years later Northern Rock would experience the first bank run in the U.K. since 1866.

Changes from partnerships to private corporations are significant because of the changes in incentives that occur. Venturing their own money, private partners are less likely to take extravagant risks than are managers putting others' money at risk, especially if their annual bonuses are tied to the amount of fees the company receives from its clients and if there is a period of at least a year before any chickens come home to roost. Moreover, if there is no clawback provision to penalise employees whose judgment later turns out to have been misguided or wrong, then observers should

9 1981 August 1: Salomon Brothers, a private partnership since its founding in 1910, sells itself to Phibro Corp., a commodities firm.
10 1997 October 1: Northern Rock floats as a demutualised building society.

not be surprised if unduly risky decisions are made.

This, after all, is what happened in the U.S. subprime mortgage market, with mortgages securitised and diced and repackaged into tranches of debt. Moreover, the Credit Rating Agencies (CRAs), companies relied on to adequately signal the riskiness of these opaque financial instruments, also faced the perverse incentive that it was the sellers of these instruments, not the buyers — those who stood to lose if the ratings were inadequate — who were the customers of their services (White, 2010).

The credit ratings history of a single instrument — a residential mortgage pool put together by GS called GSAMP 2006-S5 — exemplifies the issues of opaqueness and perverse incentives: when issued in August 2006 the best tranche in the pool was rated at AAA by Moody's; a year later it was down-rated to Baa, the lowest investment grade; four months later it was down-rated again; four months later it was further down-rated to "junk"; by the end of 2008 it was no longer being traded. While GSAMP 2006-S5 might have been a once-off, sadly it is merely a representative of a myriad similar instruments.

The CRAs, by charging fees to the companies whose products they rated, also faced moral hazard. Indeed, there was potentially a clear conflict of interest, as Hannover Re's experience can attest.[11] Moreover, because the CRAs played a mandated role since the 2004 Basel II Accord and earlier, any shortcomings in their performance could (and did) have a serious effect during the crisis. The very existence of CRAs is a testament to the existence of asymmetric information; failures of theirs contributed to overall market failure, and even CRA-shopping on the part of the issuers (White, 2010).

The issue of incentives is pervasive in the GFC: even absent the spillover effects of the systemic risks associated with the SP mortgage bubble, if the incentives are perverse, then the actions of the actors will be perverted. In this case, it is foolish to expect efficient outcomes.

Change in corporate governance

The change in corporate governance occurred in 1993, when American International Group (AIG) took control of Financial Products (FP), whose activities later crippled AIG.[12]

The alliance between AIG and FP, although a once-off, highlights the issue of the subsidiary of an insurance company betting the house in activities not central to insurance. That AIG had bought a thrift specifically in order to fall under the regulation of the Office of Thrift Supervision, a prime example of regulator shopping, is another example of AIG straying from insurance.

Moreover, there is another issue of incentives here: the entire budget of the OTS is paid by assessments on the institutions it regulates. And the OTS, a later report finds, despite overseeing several companies that are primarily insurers, had only a single employee with expertise in insurance. AIG was the world's largest insurer.

Several new technologies

The new technologies are: the 1977 invention of the first of many credit derivatives,[13]

11 See the entry of March 2003.

12 1987 January 27: American International Group (AIG) and Financial Products (FP), a new risk-management firm, sign a joint venture agreement.

13 1977: With the Bank of America (BofA),

including credit-default swaps (CDSs) in 1997,[14] whose use later laid AIG low; and the 1983 invention of the collateralised mortgage obligation (CMO), which extended earlier invention of the (mortgage-backed security) MBS.[15]

The new technologies developed in the financial sector have been touted as improving the ability of the industry to handle risk, an increase of efficiency that has been reflected in the more than doubling in the value added in the finance and insurance sector as a share of U.S. GDP (from 3.5% to almost 8%) in the fifty years from 1960 (Greenspan, 2010, Exhibit 7). And yet others, such as Paul Volcker, doubt that the newly invented derivatives have been such a boon; indeed, the very opacity of their value contributed to the freezing of the short-term credit market that the editorial in the October 2008 *FT* was referring to above, and their lack of transparency has been a high price to pay for any gains in efficiency.

An ongoing research project might seek to demonstrate the social contribution of the financial sector.[16] This is important given several things: the growth of the relative size of the sector in advanced economies (and the U.K. it was proportionately five times larger than in the U.S., according to Mervyn King); the damage caused to entire economies by the events of 2008; and not least by the size of the remuneration packages received by top managers in the sector, even in the wake of the GFC and when institutions were in receipt of government bail-out payments.

The asymmetric information that the lack of transparency of these instruments exemplifies — where few if any truly understand the value of such derivatives as CDSs — should remind us that General Equilibrium Theory (GET) assumes full information, inter alia. Indeed, some have called GET "utopian economics" (Cassidy, 2009), and contrast the elegance but unreality of this theory with "realistic economics", with its "hidden information", spillovers, and other forms of market failure. Is it an ideology to believe in the Platonic ideal of GET in the face of forty years of research which has shown that it is an ideal, but not realistic? How long after the events of 2008 will it be before some believers forget the flaws in the GET and believe in it again, thus helping set the stage for a later "Minsky moment" (Cassidy, 2009, p. 209)?

Market and extra-market events

In 1998, Russia defaulted, which led to the rescue of Long-Term Capital Management (LTCM), but no increase in regulation;[17] indeed, the 2000 *Commodities Futures Modernization Act* expressly excludes derivatives from any state or federal regulation, despite analysis done after the near catastrophe. In 2001, the Al Qaeda attacks[18] and the earlier bursting of the tech bubble led to a permissive monetary policy (with low interest rates), that, Taylor (2007) and other argue, was sustained for too long, resulting in global financial imbalances. Greenspan (2010) argues that these low short-term rates had little effect on mortgage rates, and so

Salomon Brothers issues the first privately backed Mortgage-Backed Securities (MBSs).

14 1997 December: A team at JP Morgan (JPM) develop many of the credit derivatives that are intended to remove risk from companies' balance sheets.

15 1983 June: Larry Fink is the co-inventor, for Freddie Mac, of the collateralised mortgage obligation (CMO).

16 But see Shiller (2012).

17 1998 September 23: LTCM is saved.

18 2001 September 11: The destruction of the World Trade Center.

cannot be held responsible for the subprime blowout.

The issue of the lack of savings in the U.S. and the lack of consumption elsewhere, most particularly in China, with a resulting global imbalance, might be seen as another cause of the U.S. housing bubble. And yet it might also be seen as a consequence of U.S. consumption: the Chinese (and other creditor nations) stepped in to fund U.S. consumption by buying U.S. government debt, U.S. Treasuries. I leave it for others to continue this debate.

Recent regulatory changes

In 2004, the U.S. Securities and Exchange Commission (SEC) relaxed the minimum capital requirement for securities firms and investment banks, leading to much higher bank leverage.[19] In 2007 the SEC eliminated the "uptick" rule for short sales of securities.[20] But in 2008, as a reaction to the evident crisis, the SEC began tightening regulations: in July banning "naked" short selling of several financial corporations; [21] in September tightening its 2004 relaxed capital requirements for investment banks (closing the stable door?); [22] and in October the Congress was told that the SEC had only one officer left in the Office of Risk Management.[23]

The two changes of July and September 2008 were taken in response to the collapsing mortgage market and the behaviour of the Wall Street investment banks in increasing their gearing the previous years. The earlier actions (including the underinvestment in risk management at the SEC) exacerbated the crisis, when it came: the Consolidated Supervised Entities program of the SEC was introduced in order to convince the Europeans that the U.S. investment banks operating in Europe were adequately regulated in the U.S., after pressure from the top brass of the Wall Street investment banks, who were evidently responding to a belief that the Europeans would be tougher regulators than those at home; the evidence of later testimony that the SEC was under investing in its risk management office tends to support their beliefs. The subsequent rise in gearing only made things worse in 2008. It remains to be seen whether abolition of the uptick rule had any effect: some believe that it might have strengthened the short sellers' impacts, but not everyone believes that short selling should be proscribed, even in extremis. Moreover, in the decades during which the rule was in place, the minimum "tick" had been revised from an eighth of a dollar down to a cent.

Changes in corporate behaviour

Over the past forty-odd years there have been many changes in corporate behaviour: in the 1970s, Moody's started charging fees to finance companies, rather than their customers;[24] in 1986 American pension funds started buying CMOs, their first investments in home mortgages;[25] in 1987 international

19 2004 July 21: The SEC launches the "Consolidated Supervised Entities" program.
20 2007 July 6: After 73 years, the SEC eliminates the "uptick rule".
21 2008 July 21: The SEC bans "naked" short selling of the stocks of Fannie Mae and Freddie Mac and 17 large finance companies.
22 2008 September 25: The SEC abolishes the 2004 "Consolidated Supervised Entities" program.
23 2008 October 7: Before the congressional Committee on Oversight and Government Reform, the former chief accountant at the SEC reveals that the SEC's Office of Risk Management was cut back to a single employee.

24 1970s: The CRA Moody's begins to charge fees to the companies whose products it rates, instead of the potential customers of these products.
25 1986 June: American pension funds hold about $30 bn of CMOs; three years ago none.

banks started buying CMOs;[26] in 1998 trade in CDSs began, between AIG and JPM;[27] in 1999 Fannie Mae eased the credit requirements on mortgage loans it would buy from banks and other lenders;[28] in 2004, after the SEC's agreement to relax capital requirements for investment banks, Merrill Lynch's capital ratio rose to 40:1 (or 2.5%);[29] in 2005, after its credit rating fell to AA from AAA, and it had to post an additional $1.16 bn collateral, AIG stopped writing new CDSs, although pre-existing contracts exist as I write.[30] The issuance of SP mortgages, virtually non-existent at the beginning of 1995, peaked at $125 bn in Q4 2005, only to collapse to none three years later. Without these "toxic" instruments, the firms down the line left holding the contracts would not have suffered the losses they did after the housing bubble burst, and the credit crash would not have become a financial crisis, which in turn would not have become the Great Recession, affecting people around the globe, via the purchases by foreign banks of U.S. CMOs.

I do not ascribe to the view that the managers of the institutions, by and large, were miscreants.[31] I believe that they were responding to the incentives they faced. If their actions are now seen to have contributed to the GFC, or at least to the financial crisis in the U.S. in 2008, it was because of the incentives the system presented them with.

The changes in corporate behaviour highlighted here, as well as other changes listed in the Timeline, are a function of these incentives, and in many cases, the incentives banking executives faced were a function of the beliefs of the regulators that the markets are always efficient. For example, Alan Greenspan stated that, in many ways, "private counterparty supervision remains the first line of regulatory defence." He argued that firms' reputations would keep them honest. Later, he expressed surprise that this had not occurred. Nobel Laureate Stiglitz (2009) states that his professional career has been devoted to exploring the consequences of one form of market failure — asymmetric information — that should have given true believers pause, but did not.

We should not be surprised that some self-interested banking executives lobbied, and lobbied successfully, for the regulators and legislators to alter the incentives they faced. The 1999 Gramm-Leach-Bliley Act that repealed the Depression-era Glass-Steagall Act is the most prominent example. Another is the SEC's 2004 introduction of the Consolidated Supervised Entities program, whose advent occurred much to the satisfaction of the lobbyists.

We have attempted to identify proximate causes of the GFC. Any deeper explanation of how and why these changes occurred when they did must await a more profound analysis.

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26 1987: The London office of Salomon Brothers sells $2 bn of the first tranche of CMOs to international banks.
27 1998: AIG FP begins to write CDSs, at first with JPM.
28 1999 September: Fannie Mae eases credit requirements on mortgage loans it will buy from banks and other lenders.
29 2004 July 21: Before the "Consolidated Supervised Entities" program, leverage of 12:1 is typical; after, more like 33:1 (and up to 40:1 in the case of ML).
30 2005 March 15: AIG's credit rating falls to AA from AAA; as a result, AIG has to post $1.16 bn in collateral for AIG FP's existing positions, and by the end of 2005 AIG FP stops writing CDSs.
31 Ferguson (2012) argues strongly that many banking executives were miscreants.

Which conditions were sufficient?

In Weisberg's words (2010): There are no strong candidates for what logicians call a sufficient condition — a single factor that would have caused the crisis in the absence of any others. There are, however, a number of plausible necessary conditions — factors without which the crisis would not have occurred.

We have considered a range of possible causes above: changes in legislation, changes in ownership, changes in corporate governance, new technologies, market events, changes in regulation, and changes in corporate behaviour. I would rule out some of these as causes, in the sense that they played little if any part in the unfolding of the crisis, which would likely have occurred in their absence.

I do not believe the change in corporate governance at AIG (its alliance with FP) was a cause, even if the FP division was riding on the insurers' AAA credit rating, and earning much revenue for AIG: in fact the fall in AIG's credit rating was not caused by the activities of FP,[32] although the re-rating had a clear impact on FP and AIG.

The only possible influence of the failure of LTCM (in the absence of regulation of derivatives this event might have resulted in, absent the strong opposition that prevented this) could have been that the moral hazard associated with "too big to fail" became clearer to the Wall Street investment banks: but there were so many other factors changing that it would be difficult to point to the LTCM failure and bailout as having any influence, in the absence of first-person testimony.

As I remarked above, there is no clear picture whether global imbalances were a cause or an effect of Americans' consumption and the saving habits of Chinese households: the imbalance in household saving/consumption patterns is reflected in the flows of capital and goods across the Pacific. I leave it to others to discuss this further.

There is no evidence that abolition of the uptick rules had any impact on the unfolding of events. At most, it might have made short selling of the stocks of compromised financial institutions easier, but there is no compelling evidence that such short selling, let alone the absence of the uptick rule, exacerbated the unravelling of the financial markets in 2007 and 2008.

Many of the changes in U.S. laws and regulations were in response to the development of new analyses (such as the Black-Scholes technique for pricing options) and new technologies that many believed (and still do) had improved the efficiency of the allocation of risk and intermediation of the financial markets.[33] In this case, lobbyists argued, why not relax the restrictions, some of which dated back seventy or eighty years?

Subsequently, restrictions were eased on mortgage lending, on the operations of banks and investment banks; new technologies, such as derivatives, were protected from what were evidently seen as heavy-handed regulators; investment banking partnerships became banking corporations, and owners became managers (of other people's money).

32 2005 March 15: AIG's credit rating falls to AA from AAA the day after Hank Greenberg resigns amid allegations about his involvement in a fraudulent deal with Gen Re.

33 The sector has clearly grown in relative size in the U.S. and the U.K.; whether there was a commensurate benefit to these economies before 2007 remains to be demonstrated.

These new technologies relied on the use of higher mathematics, but were often constructed using assumptions (such as normally distributed events) which later turned out to be misconstrued.

And the financial institutions responded to the changes in incentives and opportunities that resulted (often as a response to pressure on legislators and regulators from these same institutions' managers): gearing was increased; new lending with less restrictive criteria for approvals (SP mortgages, for instance) took place; there were incentives to push for easing in more regulations and to develop new forms of derivatives.

Moreover, as Charles Prince's famous quote of July 9, 2007, confirmed, firms could not afford to decline to dance, to engage in these activities on the back of the growing housing bubble — to do so would be to lose out to one's competitors, both corporate and peers, a situation not unlike an *n*-person Prisoner's Dilemma, or the famous Tragedy of the Commons.[34] But then that's what John Biddulph Martin was describing after the South Sea Bubble in 1720.

Personalities

In the first version of the Timeline, I deliberately avoided referring to individuals because I then believed the crisis was a systemic failure rather than the consequence of individuals' actions. This view is similar to that espoused in Posner (2009). In this version, I have included people's names and have also given their highest university qualification, since I think it is impossible to understand how the crisis evolved while ignoring the identities of the players, for good or ill. This approach is closer to that of Tett (2009) and others. But I do not believe that any are to blame for the crisis.

The crisis has not crept up on us completely unawares. A number of Cassandras have tried to warn us (or at least the U.S. Congress): James Bothwell in 1994; Brooksley Born in 1998 and 1999; Warren Buffett in 2007, 2008 and 2009; Ed Gramlich in 2004; Timothy Geithner in 2004; Ben Bernanke in 2005 and 2007; Richard Hillman in 2007; John Taylor in 2007; Meredith Whitney in 2007; C.K. Lee in 2008; George Soros in 2008; and, Paul Volcker in 2009 (somewhat after the event).

But these brave men and women had little, if any, impact. Arrayed against them were the optimists — most significantly Alan Greenspan, Robert Rubin, Arthur Levitt Jr., Hank Paulson, Larry Summers, Joe Cassano and Dick Fuld. Whether self-interest or ideological blindness, or a mixture of these, underpinned the optimists' arguments is not yet clear.

After the crash had occurred, it is true, Alan Greenspan did accept "partial" responsibility and later he allowed that temporary bank nationalization might be appropriate "once every century". Ben Bernanke has also spoken of the lack of regulation of AIG's financial activities, and the consequences. Others in positions of authority have been mute; perhaps they are writing their memoirs.

Europe

Beyond the U.S., the sub-prime mortgage debacle has triggered a sovereign debt crisis in the eurozone. The transmission link was that European banks had bought large numbers of mortgage-backed securities based upon U.S. home loans. As the crisis in the U.S.

34 Similarly, competition among the three main CRAs meant that adopting a more conservative ranking criterion might lose customers (the issuers of the rated instruments) to one's rivals (White, 2010).

developed, many of these loans turned bad, and in some cases imperilled the these banks. In Iceland, the banks failed. In Ireland and elsewhere the government announced guarantees: the private debt was replaced by sovereign debt. The next problem was the size of the bad debts, together with the flight of bank deposits as the plight of the banks became clearer. The size of the banking system in some European countries is much larger than the national economy (in Ireland's case, over twice the size). Hence the government guarantees are having a significant impact on the governments' sovereign debt, as reflected in rising government bond rates: the riskier the sovereign debt, the higher the rate. Moreover, higher sovereign debt, together with political pressure for government austerity, has led governments to cut their deficits. This in turn has weakened their economies.

In the case of Iceland, the local currency, the krona, collapsed, which caused pain for households that had borrowed in foreign-currency-denominated loans, but the massive devaluation provided a fillip for Icelandic exporters and so for the whole economy. Within the eurozone, however, devaluation is not an option. Its problem is that monetary union, with the common currency, is flawed: monetary policy is determined by the European Central Bank in Frankfurt, but there is no lender of last resort (such as the U.S. Fed) or European bank regulator or, most importantly, no common fiscal policy. This means that no single country in the eurozone can devalue its own currency, and it also means that there is no means for the better performing regions of Europe to support the worse performing regions, in contrast to the U.S., where Florida (and Floridians), hard hit by the bursting of the housing bubble, were supported by payments from U.S. taxpayers.

In the absence of fiscal union, the Maastricht Treaty, which sets out the necessary conditions for the monetary union that produced the euro, required annual national debt of no more than 3% of GDP and accumulated national debt of no more than 60% of GDP, inter alia. For a country to join the eurozone, it is necessary that its government budget satisfy the Maastricht conditions, an imperfect substitute for fiscal union. After the euro was launched, the Maastricht conditions were relaxed somewhat, and no country in the eurozone now satisfies the 60% limit. The case of Greece is unique, since its reported government budget before joining had been manipulated to appear to satisfy the Maastricht requirements, on advice from Goldman Sachs.

How the eurozone sovereign debt crisis will be resolved is unclear as of this writing. Both debtors and creditors (not least the northern creditor banks) would stand to lose if any country left the eurozone, an eventuality which was not envisaged in the Maastricht Treaty. At the same time, there is reluctance to advance fiscal union (which would require a loss of sovereignty by individual countries) or to develop a common banking regulator or to declare a lender of last resort for the eurozone. Are the capital controls recently introduced in Cyprus the first split in the eurozone?

Conclusions

In an earlier paper in this *Journal*, May (2011) pointed to the GFC as one of several pressing public policy issues that require rigorous analysis as a step towards appropriate policy. This paper is an attempt to begin such rigorous analysis, at least of the proximate causes of the GFC. To understand how the underlying political environment had changed in the 75 years since the Great Depression,

changes which allowed the triggers discussed above to occur, would require deeper analysis of the political economy of regulation and legislation in the U.S. and beyond, an analysis I do not attempt here.

In summary, I believe the crisis was brought on by three actions in the U.S.: first, the repeal on November 12, 1999, of the Glass-Steagall Act of 1933 (prohibiting the consolidation of financial institutions and insurance corporations), which led to a vast increase in the market dominance of the major banks; second, the Congressional decision enshrined in the *Commodities Futures Modernization Act* (signed into law by President Clinton on December 21, 2000), which explicitly exempted derivatives from government regulation; and, third, the SEC's decision on July 21, 2004, to relax the capital adequacy requirements of Wall Street banks, which allowed them to expand their leverage threefold or more. These were failures of regulation, not acts of venality. The failures of the CRAs were a symptom of the existence of asymmetric information, a form of market failure. Another way of looking at what happened is that, like the Prisoner's Dilemma or the Tragedy of the Commons, it was a phenomenon where individually rational actions were collectively irrational: no investment bank could afford not to trade in credit default swaps, since others would do so at the first bank's competitive expense, but the eventual aggregate outcome was the credit crisis. Such phenomena cannot be resolved by individuals alone, however well meaning they might be; instead, they require effective regulation, which failed here, over a period of years.

The Timeline

Available Online at the RSNSW website, http://royalsoc.org.au.

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Some aspects of the scientific development and astronomical research of Warrick Couch

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Abstract

Warrick Couch was appointed the Director of the Australian Astronomical Observatory in April 2013. He was elected a Fellow of the Australian Academy of Science in 2009 for making "pivotal contributions to our understanding of the evolution of galaxies in rich clusters and the effects of galaxy environment on their evolution and for his appointment as the primary investigator in an international team that, despite intense competition, secured one of the first allocations of observing time with the Hubble Space Telescope," according to the Academy. He was awarded an Australian Citation Laureate for 1991–1998, and is recognised as a "Highly Cited" researcher with over 20,000 citations. He previously held positions of Head of School of Physics at the University of New South Wales and Distinguished Professor at Swinburne University of Technology. He has also held the positions of the Australian Gemini Scientist and the Australian Extremely Large Telescope Project Scientist and was the Chair of the Anglo-Australian Telescope Board and a Member of the International Gemini Board. This paper discusses some aspects of his scientific development and astronomical research based on an interview the author conducted with him in 2006. It covers the period up to May 2006.

Introduction

Born in New Zealand, Warrick Couch came to Australia in the late 1970s to do his postgraduate studies at the ANU's Mount Stromlo and Siding Spring Observatories on a British Commonwealth Scholarship. Apart from a three year period spent working as a postdoctoral fellow in the UK, he has remained in Australia, making it his home. He came from a middle class family with lots of books in the house and parents who were very keen on him learning to play the piano. They made sure that he had lessons "pretty much through all my years in primary and secondary school." As a young boy he said, "I read a lot of detective stories and adventure novels." He did not read any science fiction books but enjoyed reading the science textbooks at school. He tinkered with mechanical things and played with Meccano sets and was also interested in wood work. At school "mathematics was his strong point" and he also developed a great interest in physics. It is rather surprising that he did not show much interest in astronomy as a young boy. "I don't think I ever had quite the curiosity that my father had. I didn't have the great interest in the stars that I developed later in life, particularly when I was a university student." His father was a surveyor in the Lands & Survey Department before becoming involved in geodetic computing, hence his father's interest in astronomy. However, his father was one of the influences in Couch wanting to do a science degree at

university. "In those days", he said, "a science degree was quite highly respected. In New Zealand in the early seventies, which is when I left high school and went to university, science was seen as a very attractive option, and I was very keen to pursue it."

Victoria University

He went to Victoria University in Wellington because it offered "a very good science course." It was an exciting time for him to be at university, he said, "It was a time when we just had a change of government in New Zealand from a conservative government for many years to a Labour government, and student politics was thriving at that point. It was also the time of the Vietnam War". Like many a student at that time he was involved in student protests. This included protests against the "tours of racially-selected rugby teams from South Africa to New Zealand." That did not distract him from his studies. He went on to major in physics rather than mathematics. He went into physics, he said, probably for the wrong reasons. "I chose it because most of my friends decided to do it. And we'd established a wonderful camaraderie in the first year. Friends not just locally from the Wellington area, but all round New Zealand". He had some very good lecturers, such as Professor David Beaglehole who came from a distinguished family of scientists and intellectuals. He taught him physics in his first year, which really inspired him to continue on with physics into higher years.

It was in his honours year that he turned to astrophysics under the influence of Joe Trodahl and Denis Sullivan. They gave an introductory course in astrophysics and "that's when I got really excited about it and turned to astrophysics and astronomy." Trodahl offered him a Masters research project which involved using a new piece of equipment, a photometer that Trodahl and Sullivan had designed and built. He took it down to Mount John Observatory in the South Island of New Zealand to carry out measurements on Delta Scuti type variable stars. He then took the data, in particular the observed colour variations, using stellar atmosphere models to infer the variations in the surface temperature and gravity in their atmospheres." Astronomers in New Zealand have a very strong traditional interest in variable stars, including the distinguished amateur astronomer, Frank Bateson, who ran an extremely successful variable stars program.

Mount Stromlo Observatory

When he arrived at Mount Stromlo Observatory in Canberra, he found that students did not commence their PhD projects straight away but instead "spent their first year doing several smaller projects under the supervision of different staff members." "I did two projects, one with Ken Freeman, who was wonderful to work with, and the other with Peter Wood. Peter was good to students, very helpful, and a great mentor as well." He also got to work with John Norris. They were all doing research on globular clusters and at that time Mount Stromlo Observatory was a 'mecca' for "globular cluster people", according to Couch. During his first year, he met Barry Newell who had worked in the US at Kitt Peak Observatory and had got to know Harvey Butcher and Gus Oemler who had done some pioneering work on distant clusters of galaxies with a new imaging camera. Butcher was to become the Director of the Research School of Astronomy and Astrophysics from 2007 to January 2013 which runs Mount Stromlo and Siding Spring Observatories. They had found that these distant clusters, which were at a redshift of 0.4 (considered to be high in those

days), had many blue galaxies in them. This was quite unexpected because "all the observations that had been taken over many decades of similar rich clusters at low redshift had shown that all the galaxies in these systems were generally red and there were very few blue spiral galaxies. Blue colours generally indicate galaxies that are forming stars." This result, which came to be known as the "Butcher-Oemler" effect (Butcher and Oemler 1978, Butcher and Oemler 1984), was controversial and greeted with considerable caution at that time.

This controversy motivated Newell to suggest that a lot more work needed to be done to verify the effect. He saw an exciting opportunity to do more of this work in Australia on the new 3.9-metre Anglo-Australian Telescope. After having weighed up all the possibilities as to which PhD project to undertake, Couch decided to work with Newell on "this distant cluster project." This involved a detailed photometric study of a sample of a dozen high redshift clusters, the photometry being derived from deep photographic plates mostly obtained with the AAT. As such, Couch was very privileged to work with David Malin, whose world-leading techniques for hyper-sensitizing plates and deriving uniform and accurate photometry from them were critical to the success of the project. According to Couch, "his thesis made the very important step of independently confirming the Butcher-Oemler effect and showing it to be a wide-spread and hence generally universal property of rich centrally-concentrated clusters at redshifts beyond 0.2 (Couch 1982)".

Research on galaxies and clusters

Despite these advances in verifying the Butcher-Oemler effect, there were still questions to be answered regarding the nature of the blue galaxies in these clusters. Some astronomers were questioning as to whether these blue galaxies were actually members of the clusters. Could it be the case that the galaxies are superimposed in front of the cluster or actually lie behind the cluster? According to Couch, "with photometric studies, you had to use statistical methods to actually determine whether the blue galaxies were members of the clusters. There were still some uncertainties with that particular approach". He was able to pursue these questions further when he took up a post-doctoral fellowship at the Physics Department at the University of Durham in the UK. A young and up-and-coming astrophysics group at Durham had recently been established under Dick Fong, who had moved out of particle physics to start afresh in astrophysics. It had attracted a number of innovative astronomers, such as Richard Ellis, Tom Shanks and Ray Sharples. Brian Boyle, who was to become the Director of the Australia Telescope National Facility from 2003 to 2009 (now Director Astronomy Australia Ltd.), joined the Durham group as a PhD student later. While Couch worked with all these people, his most fruitful collaboration was with Ellis, who was interested in clusters and galaxy evolution. It was to be a very productive, rewarding, and long-lasting relationship.

The main focus of the research Couch undertook with his Durham colleagues was to better understand the physical properties of the distant cluster blue galaxy populations. This involved the development and application of several new and innovative techniques, in particular the use of narrow and intermediate band filters to better characterize the galaxies' spectral energy distributions, and the utilization of the world-first optical fibre fed multi-object spectrograph on the AAT. The latter made it feasible to simultaneously gather good quality

spectra for significant samples of these faint galaxies in distant clusters (Couch 1983). According to Couch, "that revealed something quite interesting that we hadn't expected. These galaxies were not blue because they were just forming stars in the fairly sort of pedestrian way that we see in nearby spiral galaxies, like our Milky Way. But that the galaxies had undergone quite a dramatic star formation event. The star formation had occurred in what we call a burst. For some reason the star formation switched on. It was very vigorous for about a period of a billion years or so and then all of a sudden it got cut off. We were not expecting this and it really pointed to some sort of a 'star burst cycle' as we called it. For some reason the galaxy switched on, formed stars at a great rate for a certain short period of time, and then got cut off" (Barger, et al. 1996)". He and Ray Sharples developed the first detailed model which "quantified this behaviour and also explained the changes in the galaxies' spectral and photometric properties that accompanied it."

Perhaps the most exciting phase of these studies was the period where they exploited the exquisitely high spatial resolution of the Hubble Space Telescope (which was a factor of ~10 higher than that achieved in the best seeing conditions on ground-based telescopes, the latter reducing the distant cluster galaxies to fuzzy amorphous blobs in optical images) to determine, for the first time, the morphologies of the blue cluster galaxies. They were fortunate enough to receive many hundreds of orbits of Hubble Space Telescope time to pursue this project, and one which developed into a strong collaboration with Alan Dressler and Gus Oemler at the Carnegie Observatories in Pasadena, and Harvey Butcher in the Netherlands. The upshot of this was that they were able to produce a catalogue of morphological types in ten distant rich clusters of galaxies (Smail, et al. 1997). "We found that there was a mixture of galaxies in these clusters. There were certainly galaxies that we recognized very well from the nearby universe – a mixture of elliptical galaxies, S0 galaxies and spiral galaxies. But additionally, and this was a crucial discovery in terms of these blue evolving galaxies, a significant sub-set of these galaxies were quite abnormal in a number of different ways. The most conspicuous and dramatic were galaxies involved in a merger where you had two galaxies coming together and coalescing. And we caught them in the act. We also discovered that many of the spirals had a very ragged appearance, in that they were not as well structured and organised as the ones we see nearby. These were extremely important findings because it was the first ever study that had been done of the morphology of clusters and galaxies at these distant redshifts. We were seeing directly what the detailed morphological structure of galaxies was some five to eight billion years ago! Indeed that is one of Hubble's most important legacies in that it has revealed the morphology of galaxies in the distant, high redshift universe, in quite remarkable detail."

The Hubble Space Telescope observations also led to another important serendipitous discovery, the detection of "beautiful gravitational arcs" in the fields of the distant clusters. This meant the Hubble images served a dual purpose – to not only provide information on the morphology of the cluster galaxies, but to allow the distribution of the underlying, mostly dark matter in the clusters to be mapped and even more distant galaxy populations to be brought into view through the gravitational lensing effects that were observed. As such, they decided to target the rich cluster Abell 2218 (Kneib, et al. 1996), which was already a well known lensing

cluster. Their Hubble image of this cluster turned out to be spectacular, and has become known world-wide as the most famous gravitational lensing picture that has ever been taken. To fully exploit all the information that was contained within it, John Paul Kneib, a young post-doctoral lensing expert from France was hired, and he "did all the modelling of the lensing features that were observed, using them to quantify and map the dark matter content of the clusters and then, in turn, to derive the distances and luminosities of the more remote galaxies that were being lensed by the cluster."

Couch's work was not just confined to studying the blue galaxy populations in distant clusters. In his paper on spheroidal populations in distant clusters (Ellis et al. 1997), the attention was focused on studying the red galaxies in these systems, which were thought to be dormant in star formation for many billions of years and hence very old. According to Couch, "There are various techniques for doing this, but we used the approach of measuring the scatter in the combined ultraviolet and optical colours of these galaxies. Such colours are quite diverse in galaxies forming stars, with their scatter only slowly decreasing over several billion years after star formation has ceased. This behaviour can be quantified using galaxy population models, allowing 'age' measurements, or rather the time since the last epoch of major star formation, to be made from the observed scatter. What we confirmed was that these objects had been around for a very long time. Probably they would have been formed at least beyond redshifts of two or three. This is important to know because that puts important constraints on models of galaxy formation. At the time there were models suggesting that galaxies could have formed as recently as a redshift of one. In particular, the hierarchical models for galaxy formation had galaxies forming continuously right through from the Big Bang until now through mergers and accretion. I think we were able to address those sorts of questions that were raised by those models."

Distant supernovae studies

In 1989, Couch was involved in the first ever discovery of a Type Ia supernova at cosmological distances, in this case at a redshift of 0.3 (Norgaard-Nielsen et al. 1989). According to him, "people had been trying to find supernovae at redshifts beyond 0.2 and 0.3. We were very fortunate to be the first ones to do so". This led to his collaboration with the astronomers who were involved with the Supernova Cosmology Project (Perlmutter et al. 1999) which was led by Carl Pennypacker and Saul Perlmutter from the University of California, Berkeley. The goal of this project was to detect high redshift Type Ia supernovae and use them to measure the cosmological parameters, in particular the value of the cosmic deceleration parameter, q_0. Their work on the cosmological parameters had implications for the nature and structure of the universe. Their results produced a new paradigm for the nature of the change in the rate at which the universe was expanding. According to Couch, "I remember very well how cosmology changed over the course of our distant supernovae campaign. At the beginning of it all, the standard model at the time was a universe which was flat, because all the theorists were telling us that the universe had gone through an inflationary period, which forced it to be flat. But any concept of there being a cosmological constant, with the implication that the universe's expansion was speeding up, was just not even contemplated. Rather, everyone subscribed to the view that the energy content of the universe was all tied up in matter, the gravitational effects of which

caused the expansion to slow down over time, and there was not any dark energy." But this was about to change as they began discovering more and more high redshift Type Ia supernovae out to redshifts as high as one. Being quite precise 'standard candles', these objects "could do a much better job of constructing the Hubble diagram, resulting in the discovery of this quite remarkable and unexpected result," he said. They found that the universe was accelerating, with the implication that "dark energy" was causing this acceleration. In fact, the rival group led by Brain Schmidt from the Australian National University had also come to the same conclusion pretty much at the same time, based on their own distant Type Ia supernovae search. According to Couch, "I remember meeting Brian and we were comparing the results of the two teams, which were pointing very much to the same thing. It was a remarkable result. And I remember Brian saying this is such a scary thing and we don't really want to believe it, but our team is basically coming to the same conclusion." The accelerating universe was a major discovery, and was subsequently recognized as such by the award of the Shaw Prize to the leaders of the two teams, and the 2007 Gruber Cosmology Prize to all the members the two teams and more recently the award of the 2011 Nobel Prize in Physics to Perlmutter, Schmidt and Reiss (Schmidt, et al. 1997).

Couch has an excellent record of high citation rates for his publications. He attributes this to having worked in teams. "Most of my papers involve collaborations and I think this is the key part of my strategy." "I also think picking areas where you can make an impact is so important, and I guess I have been very fortunate to work with the right people and be in the right place at the right time and have access to major new telescopes, instruments and technologies." His papers with Richard Ellis and his collaborators with the Hubble Space Telescope made a huge impact. Some of his earlier papers, based on data obtained with the Anglo-Australian Telescope, also had a significant impact. According to him, "this was because we were the first groups to use optical fibres to observe many galaxies at one time in a cluster and therefore build up a much more detailed set of spectroscopic observations. This allowed us to understand in more detail what is going on in these clusters."

He is actively involved with the 8-metre Gemini telescopes and the next generation of "extremely large telescopes" (ELTs). In fact, he was the Australian Project Scientist for both these telescopes. The ELTs are envisaged as optical infrared telescopes "that will have an aperture of somewhere between two to three times that of the current eight and ten metre telescopes. So we are talking about a 20 or 30 metre telescope. They will undoubtedly be ground-breaking and broad ranging in terms of their scientific capabilities." According to him, "It is extremely important that Australia gets involved in an ELT project if it is to maintain its excellence in optical/infrared astronomy, and we are looking to do so at this current time." In their Decadal Plan for the 2006-2015 period, Australian astronomers have given the highest priority to three things: development and prototyping of the Square Kilometre Array (SKA), membership of an ELT, and increased access to 8-metre class telescopes. According to Couch, "one of the main strengths of Australian astronomy is that it is a very cohesive research community which, at the same time, has a healthy amount of diversity and yet strong synergy between the different areas, particularly between optical and radio astronomy. I think in the next five to ten years our main challenges are

going to be in terms of maintaining that excellence."

Conclusions

As to his major achievements to date (May 2006), he said, "he was pleased with his achievements at the University of New South Wales in seeing the School of Physics through a difficult process of "regeneration and generational change." "Compared with a lot of my colleagues whom, I think, would be content to simply stay put in their comfort zone, I have been very eager and fortunate to become involved in new projects and initiatives, such as Gemini and ELTs." This paper has reviewed some aspects of the life and astronomical research of Warrick Couch up to May 2006. A subsequent paper will review his scientific work from June 2006 to 2013.

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Nested partnerships and interdisciplinary science: from the National Medical Cyclotron to the research cyclotron of the National Imaging Facility

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Abstract

In Australia, the routine use of medical isotopes produced by a prototype cyclotron for diagnostic imaging commenced in the early 1990s. Since then, the mainly clinically focused imaging in nuclear medicine has become a broader and more interdisciplinary endeavour. As 'molecular imaging', it has become a field that supports a wide range of basic, translational and clinical research and draws in skills from many areas, including physics, chemistry, engineering, biology and medicine. Such growth has been accompanied by the emergence of scientific collaborations well beyond individual institutions.

This paper provides the historical context to the former National Medical Cyclotron (NMC) facility (1992-2009) at Camperdown, Sydney and the subsequent partnerships that led to its refurbishment as the new site of the National Imaging Facility (NIF) Cyclotron, a flagship research facility enabled by the National Collaborative Research Infrastructure Strategy (NCRIS). It is now the centrepiece of a physical research infrastructure as well as a growing network of collaborations that open up access to medical isotopes for research and clinical applications across Australia to new users and applications. It is also a contemporary example of how science has moved from individual scholarly endeavour to highly networked activity.

The funding model initiated through NCRIS included shared funding, funding leveraging and in-kind contributions primarily for the establishment of the large instrument and laboratory infrastructure rather than their operational costs. Here, we illustrate how partnership arrangements emerged at institutional, state and national level and how they address the task of providing open access to, and sustainable operation of, a major piece of research infrastructure that spans multiple institutions.

Introduction

Molecular imaging is the visualisation, characterisation and measurement of biological processes in humans and other living systems at the molecular and cellular levels. Molecular imaging typically consists of 2- or 3-dimensional imaging as well as quantification over time. The techniques used include radiotracer imaging/nuclear medicine, magnetic resonance (MR) imaging, MR spectroscopy, optical imaging, ultrasound and others (Mankoff 2007).

Molecular imaging using medical isotopes for clinical diagnostics and research into cancer, cardiovascular, immunological, as well as nervous systems diseases is one of the most important applications of the radiotracer principle first utilised by George Charles de Hevesy in 1911 (Hevesy 1923, Myers 1979). There is a broad range of isotopes, the reactor-produced Tc-99m being the predominant isotope for routine clinical applications, while the cyclotron-produced isotopes, such as I-124, I-125, I-131, C-11, F-18 and others have clinical as well as research uses. Notably, C-11 is the isotope of choice for research since it allows the labelling of organic molecules with relative ease without introducing into the molecule atoms other than carbon that might alter its functional properties. However, since C-11 has a short half-life of only 20.38 min, such work can only be carried out if the source, i.e. the cyclotron, and the radiochemistry and imaging laboratories are in close proximity.

Technically and operationally challenging and dependent on highly skilled staff, non-invasive, radiotracer-based molecular imaging requires substantial up-front and ongoing operational investments. Recent reviews initiated by federal and state departments (McKeon review (Ministry of Health 2013) and the Wills review (NSW Ministry of Health 2012)) of the existing practices in biomedical research have, therefore, emphasised the importance of partnerships across often competing institutions and the formation of research hubs that promise better use of resources and sharing of knowledge.

> *"The challenge for the 21st century is to understand how the casts of molecular characters work together to make living cells and organisms, and how such understanding can be harnessed to improve health and well-being… this quest will depend heavily on molecular imaging, which shows when and where genetically or biochemically defined molecules, signals or processes appear, interact and disappear, in time and space."* (Tsien 2003).

Such a research hub has been created at Camperdown, Sydney, a research precinct that amongst others is home to the collaboration between the University of Sydney's Brain and Mind Research Institute (BMRI) and the Australian Nuclear Science and Technology Organisation (ANSTO), both with strong research interests in the development and use of medical isotopes and molecular imaging.

ANSTO currently operates at a number of sites: Lucas Heights, which is 40 km south of Sydney and the site of Australia's only research reactor as well as a number of large accelerators; the ANSTO-Camperdown site, formerly the National Medical Cyclotron (NMC), which is adjacent to the University of Sydney; and the Australian Synchrotron, which is located in a growing research precinct in Clayton, Melbourne.

Three initially independent, partly visionary, partly pragmatic developments came together to form a partnership that is now the

University of Sydney node of the National Imaging Facility in the Camperdown precinct:

- an initiative of the University of Sydney under the then Vice-Chancellor Gavin Brown to reinvigorate some of its basic neuroscience research, join it with clinical research and place it under one roof at the Brain and Mind Research Institute (BMRI), while making better use of partly vacant, formerly industrial spaces that the University owns at its Camperdown site;
- the participation of the BMRI in a federal research infrastructure development initiative, after having received substantial Commonwealth, State and philanthropic funding to undertake interdisciplinary basic and clinical research into mental health. Notably, philanthropic seed funding was received from the Clive and Vera Ramaciotti Foundation for an experimental positron emission tomography (PET) scanner to establish a Brain Imaging Laboratory, which established the need for radioisotopes and radioligands for research that could not be provided with sufficient priority through the clinical cyclotron at the nearby Royal Prince Alfred Hospital;
- and the formation of a more research-intensive ANSTO Radiopharmaceutical Research Institute (RRI), later to become the broadly mandated ANSTO LifeSciences, which needed medical isotopes for research that ANSTO's own ageing National Medical Cyclotron (NMC) at Camperdown could not easily supply. Details on the NMC's development and its demise are addressed in a separate section.

Below, we provide part historical narrative, part description of how the National Collaborative Research Infrastructure Strategy (NCRIS) and the Science Leverage Funding mechanism of the New South Wales Government lead to the formation of the National Imaging Facility (NIF) at Camperdown and discuss some of the broader aspects of interdisciplinary and networked science.

The Partners

National Imaging Facility (NIF) and the National Collaborative Research Infrastructure Strategy (NCRIS)

In 2005, the federal government of Australia launched an initiative investing $542 million over 2005-2011 in support of infrastructure and networks necessary for world-class research (NCRIS 2005). Twelve priority areas were identified, which resulted in a roadmap with the following funding and capabilities:

- Evolving Biomolecular Platforms and Informatics (includes associate membership of European Molecular Biology Laboratory) ($53 million);
- Integrated Biological Systems ($40 million);
- Characterisation ($47.7 million);
- Fabrication ($41 million);
- Biotechnology Products ($35 million);
- Networked Biosecurity Framework ($25 million);
- Optical and Radio Astronomy ($45 million);
- Integrated Marine Observing System ($55.2 million);
- Structure and Evolution of the Australian Continent ($42.8 million);
- Platforms for Collaboration ($75 million);
- Terrestrial Ecosystems Research Network ($20 million); and
- Population Health and Data Linkage ($20 million).

Five expert working groups were established to review the roadmap, with four of these aligned with the National Research Priorities (Environmentally Sustainable Australia, Promoting and Maintaining Good Health, Frontier Technologies, Safeguarding Australia). In addition to the fifth expert working group covering the Humanities, Arts and the Social Sciences, an ICT Strategy Group identified and synthesised current and future ICT research infrastructure requirements.

The characterisation capability became constituted as the Characterisation Council (DIISR 2008, DIISR 2010) which consists of the National Imaging Facility (NIF), the Australian Microscopy and Microanalysis Research Facility (AMMRF), the National Deuteration Facility (NDF), the Australian Synchrotron and the Australian Synchrotron Research Program.

Seven founding members (University of Queensland, University of New South Wales, University of Western Sydney, University of Sydney, Monash University, Florey Institute of Neuroscience and Mental Health, Large Animal Research and Imaging Facility) formed the National Imaging Facility consortium. The funding scheme stipulated that the institutional investment would receive matching contributions from federal (through NCRIS) and state governments.

A subsequent expansion programme included the University of Melbourne, Swinburne University of Technology, the University of Western Australia and ANSTO. Matching contributions were provided by the state governments of New South Wales, Queensland, South Australia and Western Australia. Figure 1 shows the funding contributions from various sources to the new research infrastructure and the creation of partnerships nested in a larger network. The overall evaluation of NCRIS in 2010 (DIISRTE 2013) concluded that the initiative had been successful in engaging the Federal Government, the State and Territory Governments and government agencies in the priority areas without compromising a national approach to funding the intended research infrastructure.

The joint University of Sydney/ANSTO node of NIF is dedicated primarily to tracer-based molecular imaging and radioligand development. As a shared facility, it now provides the research community with open access to cyclotron-based radioisotopes (F-18 and C-11) and radiochemistry/pre-clinical imaging technologies mainly for collaborative, publicly funded research while also allowing for some commercially supported research. The NCRIS-funded flagship instrument, a research-dedicated 18 MeV cyclotron and associated radiochemistry hot cells (Figure 2B), is located in the ANSTO Camperdown facility, close to the BMRI, and is supported by the expertise of ANSTO cyclotron engineers and radiochemists.

At the inception of NCRIS and NIF, ANSTO still operated the NMC (Figure 2A shows hot cells at the NMC), and retained an observing position vis-à-vis the NIF consortium. As ANSTO pondered the options of whether and how it should continue supporting research using cyclotron-produced medical isotopes, whether to decommission its site at Camperdown or to re-engage in research, a new convergent dynamic towards partnerships became apparent. Below follows the history of the National Medical Cyclotron.

A 

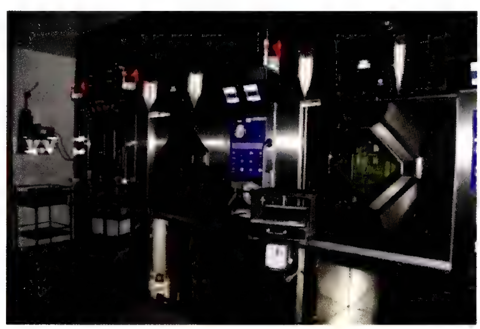
B 

Figure 2: Hot cells (A) at the NMC were designed to handle comparatively long-lived single gamma-emitting radioisotopes (often requiring external manipulators) and short-lived positron-emitting radioisotopes, whereas the hot cells at the new NIF node (B) handle positron emitters only (C-11, F-18).

The National Medical Cyclotron (NMC)

The history of the NMC illustrates the various modes of government influence in the development of scientific infrastructure. Cyclotron science in Australia goes back to Sir Marcus Oliphant's return from England in 1948, to establish the physics research program within the new Australian National University. However, his planned Australian cyclotron never materialised due to runaway costs and technological complications, subsequently becoming known as "The White Oliphant".

44 years later, spurred by a sense of national need within the medical community, Australia came to operate its first cyclotron, albeit for medical rather than physics research applications. At the Royal Prince Alfred Hospital (RPAH) in Camperdown, the NMC was commissioned on 13 March 1992. It represented nine years of planning and construction, but nearly half a century of ambition.

The proposal

In 1979, the predecessor to ANSTO, the Australian Atomic Energy Commission (AAEC), formed a national cyclotron advisory committee with representatives from all States as well as federal bodies such as the National Health and Medical Research Council and the Australian Radiation Laboratory to advise on the need for a cyclotron for the production of medical isotopes. Although the committee provided support for a national cyclotron, as well as a National Institute of Nuclear and Radiation Medicine, the committee's work resulted only in a series of proposals to government over the next half-decade.

In 1983, an ad-hoc committee, chaired by Professor Tony Basten of the University of Sydney and RPAH, took ownership of the national cyclotron concept. In the context of gaining funding from the 1983 federal budget, the concept was placed before government, through the Minister for Health, as a new policy proposal. The Minister for Health appointed the Medical Cyclotron Committee (MCC) to examine in detail the need for a national cyclotron. For this, the AAEC submitted the original proposal for a dual-purpose cyclotron for commercial production and research, taking the single purpose commercial option off the table. Competing with the AAEC's proposal was one from Austin Hospital in Melbourne, for a single-purpose radioisotope production facility, of lower energy and lower cost. The committee was tasked with producing a recommendation based on cost-benefit analyses of each proposal.

The Australian Medical Cyclotron Workshop (Canberra, 14 December 1984) recommended that the facility should be located within close proximity to nuclear expertise, such as that available at the AAEC; and that it be located within a teaching hospital, such as the RPAH, to ensure both the production and research capabilities could be exploited – a dual-purpose cyclotron, excluding by implication the Austin Hospital proposal. With strong support from both the domestic and international medical communities, the Committee recommended that the federal government support the AAEC proposal for a dual-purpose national cyclotron located at RPAH, but the cost-benefit justification for establishing such a facility, as judged by the MCC, was based primarily on the research applications being made available. However, the MCC recommendations were not a guarantee that the cyclotron would be built, as the Minister

for Health endorsed the recommendations in principle, but was reluctant to release funds from within the Health portfolio. The Minister for Resources and Energy, as the Minister responsible for the AAEC at the time, committed to pursuing the project through the Resources and Energy portfolio, and announced the Cabinet decision to that effect in August 1986. Regardless of Cabinet's decision, the Austin Hospital forged ahead with its cyclotron plans and gaining funding.

The planning

As a dual use facility, the cyclotron's planned objectives were mixed. First, it was to produce radioisotopes on a commercial basis for distribution to nuclear medicine departments in hospitals throughout Australia for use in the clinical diagnosis of a wide variety of health conditions, and thus discontinue expensive imports. Reactor-produced radioisotopes (from the research reactor at AAEC) would complement the cyclotron-based radioisotope production. Second, the plan emphasised the production of very short-lived radioisotopes for use in a national positron emission tomography (PET) diagnostic and research centre associated with the cyclotron. Medical research studies at the PET centre were expected to improve understanding and treatment of many common medical conditions of high social cost, including, for example, industrial/occupational disorders.

Initial plans developed for the NMC, based on the AAEC's 1984 workshop submission, included multiple beam rooms, a radioactive component store, a briefing and conference room, and a display area, around the centrepiece – a 40 MeV cyclotron. However, capital costs had been significantly underestimated, and in February 1987, it was decided to review and amend the project. As a result, there would be only one beam room; production laboratory space was reduced by 30%; the area occupied by the two quality control laboratories was reduced by 35% and 40% respectively; the main store shrank by 20%; the conference room and display area were eliminated; and the number of hot cells for radiopharmaceutical production reduced from ten to five, and for PET from five to three. Most notably, the planned 40 MeV cyclotron was downgraded to 30 MeV, with the selection of a negative ion cyclotron in order to deliver an equivalent production output. Upon completion of the facility, the National Medical Cyclotron represented a $22 million investment in Australian nuclear medicine, double the initial 1985 estimated capital cost of $11.05 million.

Operating the National Medical Cyclotron

On 13 March 1992, the National Medical Cyclotron was opened by the Governor-General Bill Hayden (ANSTO 1992), achieving regulatory approval for the production of specific radioisotopes for medical use in late 1992; the facility produced 130 batches of F-18 and 30 batches of N-30 to the end of the 1992/93 financial year. At the end of the 1993/94 financial year, sales of Th-201 and Ga-67 represented more than one quarter of ANSTO's Australian Radioisotopes' (ARI) total sales. The vast majority of ARI's total demand for these isotopes was provided for by the NMC.

In keeping with its dual-purpose mandate, the NMC made contributions to research. Quantities of I-123 were produced and provided to researchers in Melbourne and Adelaide, and iodine was incorporated into several radiopharmaceuticals for use in clinical trials. However, there was an emerging perception that the facility was being under-utilised, partly as a result of the conflict

between its intended uses. In May 1994, a comprehensive review was undertaken with external consultants from Bain International Inc. and the Battelle Memorial Institute. The Bain & Battelle Review (Bain International 1994) recommended, inter alia, that management of the NMC be transferred to an organisation within the health and medical community, and that mechanisms be sought for spinning off the commercial activities of ARI and the ANSTO Biomedical Health Division as most of the biomedical and radiopharmaceutical activities being undertaken by ANSTO did not seem to fit within its ongoing activity mix. The potential challenges in running a dual-purpose cyclotron became apparent as the NMC at the time was commercially successful but was lacking in research activities, mainly due to the physical and perceived cultural separation of ANSTO from the health and medical community, and the apparently fragmented nature of the nuclear medicine community. During this critical review period, ANSTO's radioisotope leadership position remained vacant, see Figure 3.

After the 1994 review, the NMC continued to be managed by ANSTO throughout its operational life, under changing government and organisational leadership (Figure 3). Commercial and research radioisotope activities at ANSTO were formally separated in 2004. While commercial production was looked after by ARI, a newly created Radiopharmaceutical Research Institute (RRI) was tasked with developing ANSTO's research using medical isotopes (Figure 3). Notwithstanding this clearer separation of commercial from research activities, the NMC continued to provide mainly commercial radioisotopes and research output or support of research remained minimal.

Replacing the NMC

Ten years later, a major change in the way ANSTO would contribute to research using cyclotron-produced isotopes was signalled as the University of Sydney consolidated many of its clinical and basic neuroscience capabilities in 2004, with the opening of the Brain and Mind Research Institute (BMRI). The institute became home to The Ramaciotti Imaging Centre, a core facility for brain imaging research at the University of Sydney. Brain imaging and molecular imaging using radiotracers is an important tool in understanding the neurochemistry of the living brain. The University of Sydney's participation through the BMRI in the NCRIS was aimed at completing the infrastructure with a research-dedicated radiochemistry facility that would eventually lead to the development of a flagship instrument, the NIF cyclotron. A number of options were entertained, and the University tendered for a cyclotron operator with an operational model that would secure provision of C-11 and F-18 for research purposes. ANSTO submitted a proposal for an extended research partnership. Thus, in 2008, a year after funding from NCRIS had been awarded, an agreement was reached that ANSTO, with its knowledge and expertise of two decades of operating the NMC, would partner with the NIF to operate the new NIF cyclotron as well as undertake joint research with its university partners. With this agreement, an alternative was found to the loss of a unique and strategic inner city presence for ANSTO and the replication of existing infrastructure by the university. The NMC ceased operations in October 2009 (Figure 3). The new NIF cyclotron facility (see new hot cells in Figure 2B) was inaugurated by NSW Governor Professor Marie Bashir on 6 December 2011 (Figure 4), in the presence of the Vice-Chancellor of the University, Dr Michael Spence, and a large

gathering from all parts of the university, ANSTO and federal, state and local government. It thus became, in the words of the Vice-Chancellor at the earlier signing of a Memorandum of Understanding between the partners, one of those 'ritual moments'. It symbolised not only the long partnership of the University with ANSTO, but also a vision for a more integrated approach to science that crosses faculty boundaries and institutions.

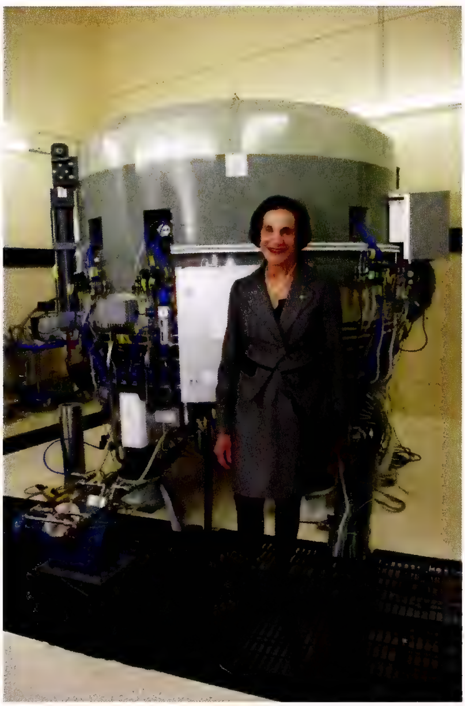


Figure 4: NSW Governor Professor Marie Bashir in front of the new cyclotron during the opening on 6 December 2011.

This outcome has fulfilled some of the predictions of the MCC (ADH 1985) and some of the recommendations of the Bain & Battelle Review (Bain International 1994) in regard to ANSTO's distance from the medical and health community. Counter to the thinking at the time, the field of life sciences today can no longer be seen as an ill fit within a nuclear science and technology organisation which only provided routine medical isotopes for nuclear medicine. The technical advances and conceptual maturation of the life sciences over the last twenty years now give nuclear science and technologies an indispensable role in probing the fundamental structure of living matter, be this by scattering techniques using neutrons or X-rays or by using isotopic techniques for tracing and tracking in complex biological systems from cells to biospheres. With the advent of systems biology and its many applications ranging from food production to nutrition to human health, the life sciences have begun to link more directly with the environmental sciences, for which dating and tracing by isotopic techniques has long been the approach of choice.

Different partners – different cultures

The overarching institutional partners, ANSTO and the University of Sydney, are both substantially publically funded. ANSTO has a defined mandate to maintain, apply and extend knowledge and capabilities in nuclear science and technology, whereas the University is a provider of to varying degrees research-led higher education. ANSTO has been organising itself around core nuclear science and technology capabilities, for which it maintains large research infrastructure. The University aspires to be the home of well-rounded academics striving for research excellence and supporting teaching. Notwithstanding that many differences are only by degree, ANSTO's organisational model gravitates towards teams often structured along technical skills or scientific instruments, while the University model promotes scholarly, usually individual, success. Therein, however, lies a contemporary dilemma. How can individualised activity match challenges that require a collective effort, and how can

technical skills-centred capability be recruited into the creative and innovative process by which those challenges are to be met?

The partnership between the University of Sydney and ANSTO has grown out of the interaction of two recently formed organisational units: the BMRI and ANSTO LifeSciences. While the BMRI is driven by a broader societal demand for knowledge-based improvements in mental health, a task for which it recruits material and intellectual support across faculties and institutions, ANSTO LifeSciences has changed its model from service provision and facility operations to active engagement in partnerships focused on solving specific problems.

Below we present some of the governance approaches and human aspects that have come to the fore in the partnership.

Open access and integration

Partnerships are not only intended to build shared physical infrastructure, but also to create social capital for the individual employee and increase performance of the partnering organisations (Andrews 2010). In science and technology, in particular, most advances now rely on having access to networks of knowledge (Wagner 2008).

The partnership between ANSTO and the BMRI and the wider network of the NIF is an example of a local network nested in a wider national and international network in which the scientific and technological capabilities can no longer be provided by a single institution. This nested structure reflects the funding model under which investments come from various bodies, such as the Ramaciotti Foundation, University of Sydney, ANSTO and Federal and State government departments, see also Figure 1. Government can either directly fund new initiatives, or participate in a leveraged co-funding scheme, such as the NSW Science Leverage Funding mechanism. Such multi-stakeholder engagement is particularly common in the life sciences. According to a recent study by the OECD, the interdisciplinary nature of the life sciences and the specific technological, economic and industrial environment of the medical and health sector foster multi-stakeholder engagements that create knowledge networks as a means to identify new markets (OECD 2012).

One of the challenges is to ensure open access to the research infrastructures. Access policies need to enable high quality research and good use of the facilities, as well as a diverse range of projects. The schematic in Figure 5 shows the process by which access can be organised and has been adopted by the ANSTO-BMRI-NIF partnership. An analysis of the publication output under NIF showed that the University of Sydney-ANSTO NIF node doubled its yearly output to more than 50 peer-reviewed papers in 2011, i.e. prior to the new cyclotron becoming operational (NIF 2013). This illustrates the general growth in the interdisciplinary field of molecular imaging. The data on research output since the new cyclotron was commissioned (December 2012) are not yet available.

In multi-stakeholder research facilities, there is a constant need to reconcile the different priority amongst the partners, who may cater to different research communities. At the Camperdown facilities there are a series of different access routes: either via NIF, ANSTO, or the BMRI. The partners have created formal open access portals as a way to 'democratise' access to the research infrastructure, taking account of their different foci.

Although there are different access routes, all partners have incorporated a review procedure by experts who evaluate the proposals on scientific merit and feasibility, resource availability as well as strategic considerations. The allocation process includes monitoring throughout the project.

The ANSTO-BMRI-NIF platform provides access to a dedicated research cyclotron and radiochemistry capability that includes the development of either already validated or new radiopharmaceuticals at the ANSTO Camperdown facility that, in the case of short-lived radioisotopes, are deployed to the nearby imaging laboratories at the BMRI. These laboratories are equipped with multi-modality preclinical and clinical scanners that use the molecular probes to measure specific biological functions related to disease. In addition, a high performance computing platform provides advanced imaging analysis and modelling.

While ANSTO LifeSciences, BMRI and the NIF have expertise in the areas described, the important added value from this partnership, such as the transfer of knowledge in radiochemistry, imaging data acquisition, data analysis, radiolabelling, and animal models of disease, comes through collaborations with domestic and international scientists, i.e. the respective peer networks of each partner. What in fact emerges is a collective system of knowledge creation, transfer and application.

Varied research groups with a defined focus, such as the ANSTO-BMRI-NIF collaboration, are vital for innovative approaches in life sciences, as pointed out in the OECD paper on 'knowledge networks and markets in life sciences' (OECD 2012). This has been recognised by recent strategic reviews into health and medical research in Australia, i.e. the McKeon review (Ministry for Health 2013) and the Wills review by the state government of New South Wales (NSW Ministry of Health 2012). Both emphasise that the current publicly funded research effort is in need of a better integration between fundamental health and medical research if improved health outcomes and economic benefits are to be realised. It remains to be seen how these calls will influence the existing institutional structures, notably the faculties and disciplines in the higher education sector, and how their epistemological traditions and business models will develop. In any case, the NSW review echoed the international experience that the two major elements of publicly funded research, namely world-class research infrastructure and translation of research into applications, require systematic incentives to build partnerships, which implies the active removal of intra- and inter-institutional barriers. The reviews also acknowledge that the approach has to be long-term, since research impact can be assessed only after a lengthy period of time; "Studies suggests that it takes an average 17 years for research evidence to reach clinical practice" (Balas 2000).

Although the driving force of a network may often be only a small core group of researchers, the broader networking activity promotes learning through more diverse feedback and a 'collective intelligence' that enables better decision making. In regard to this aspect of social capital, Malone (Malone 2012) identified essentially three factors that determined the success of a 'collectively intelligent' group:

- the average social perceptiveness of the group members. The higher the individual ability of participants to read other people's emotions, the more collectively intelligent the group;
- the evenness of conversational turn taking. Groups where one person dominated the conversation were, on average, less intelligent than groups where the speaking was more evenly distributed among the different group members; and
- a good gender balance, whereby a high percentage of women resulted in a greater social perceptiveness effect.

A glance at the senior management involved in the ANSTO – BMRI partnership shows that at the time of writing two out of five are women, most are scientists (albeit from different fields) and most have lived or come from abroad.

Partnership between ANSTO and BMRI

A formal Research Collaboration Agreement defines the principles of the collaboration of the partnership. The day-to-day activities of the ANSTO – BMRI partnership lay in the

hands of two committees: the Steering Committee and the Operations Committee. Whereas the Steering Committee develops the strategic objectives related to research as well as communications and outreach activities, the Operations Committee assesses and schedules all research projects that require access to the facilities and is also responsible for establishing and implementing policies and procedures for the operation of the facilities, including training, maintenance and similar (BMRI 2013). In addition, each partner has their own formal reviews with external assessment that evaluate the outcome of the collaboration.

A general perspective on the workings of inter-organisational networks has recently been given by Gardet and Modet (Gardet 2011) who undertook case studies of innovation networks and their various mechanism of coordination. Their research showed that the following mechanisms advance projects in innovation networks:

- an equitable division of outcomes when outcomes were agreed 'ex ante' decreases the risk of opportunism and thus equity distribution advances the project;
- trust complements formal mechanism; relying on trust in competences is more beneficial than relying on goodwill;
- guarantees should include not only finances, but also special assets and brand image;
- the use of another network member as an arbitrator can facilitate conflict resolutions.

Although robust coordination mechanisms are vital in setting up networks, it is finally human factors, such as a high level of staff and user satisfaction that makes a partnership function well (Andrews 2010). Choi and Pak (2007) discuss the promoters, barriers and strategies that enhance multi-, inter- and trans-disciplinarity. The processes they identified for creating synergies amongst team members are the 'fourteen Cs of teamwork': Communication, Cooperation, Cohesiveness, Commitment, Collaboration, Confronts problem directly, Coordination of efforts, Conflict management, Consensus decision making, Caring, Consistency, Contribution, as well as Corporate support and Chemistry (personality) (Choi 2007, Wiecha 2004), but they also point out a number of barriers that need to be reduced in order to progress a network. In our experience, it is particularly important to remove barriers due to differences in organisational processes and culture. These include (i) differences in processes, such as budgeting and accounting; (ii) differences in institutional jargon; and (iii) differences in the direct influence that top management may or may not exert on the directions of the partnering groups. Ongoing efforts are necessary to provide (i) continuous opportunities for get-togethers to foster and renew engagement in the collaboration; (ii) regular reviews of the impact of the work undertaken and the measures of impact; as well as (iii) careful measures that ensure fair and continued project ownership in order to maintain the motivation to translate research achievements into shared outcomes.

In summary, networks require continual negotiation of differences in order to advance research. In this context, early career development and mobility is another aspect where networks play an important role. Large networks offer inherently better opportunities for workforce mobility, which is a particularly strong motivator for researchers, who move abroad not only for advancing their career, but also for the exchange of ideas and broadening their knowledge (Baruffaldi 2012). In the final part of our paper, we, therefore, look at some of

the training and educational aspects of the partnership.

Education and training

Education and training, is generally provided in the context of defined disciplines. However, molecular imaging is interdisciplinary. It has been pointed out (Bammer 2013) that in order to strengthen interdisciplinary practice and capacity, a re-think and co-ordinated activity would be required. This would include developing agreed frameworks, compiling and classifying what we already know and turning isolated individuals and groups into co-ordinated networks of peers and potentially new disciplines.

Molecular imaging is strongly interdisciplinary with multiple overlapping engagements, as illustrated in Figure 6. Thus, skill acquisition in molecular imaging is complex and needs to be supported by a range of different educational providers, including vocational and tertiary education institutions as well as professional associations and interest groups.

In molecular imaging, we see thus "a team composed of members of a number of different professions cooperating across

disciplines to improve patient care through practice or research" (Choi 2006). In the process, discipline boundaries are crossed and developments in one discipline are transformed into the new concepts of another: science has become transdisciplinary. Since the degree to which disciplinary boundaries are crossed or convergence of disciplines is seen as advantageous varies along a continuum, Choi and Pak (Choi 2006) have also proposed the term 'multiple disciplinary'. Indeed, the educational activities in molecular imaging retain elements seen as foundational to a discipline, as well as elements that cross disciplines.

At present, the educational opportunities in molecular imaging include a Master of Molecular Imaging (Master Molecular Imaging 2013) jointly offered by several university partners, as well as vocational training through a professional development program 'Foundations of PET-CT' (Foundations of PET-CT 2013) and a distance-assisted training (DAT 2013) for Nuclear Medicine Professionals (sponsored by the International Atomic Energy Agency – IAEA). The need for collaboration in this area is underlined by the structure of the programmes: the Master's course is a collaboration between three universities – University of Sydney, University of Queensland and University of Singapore; and the vocational training is a combination of distance-learning and hands-on experience, with the practical activities taking place in different locations in Australia. The Master's programme, as well as the professional development training, makes extensive use of on-line modules. Recent studies into the future of learning emphasise that massive open on-line courses, MOOCs, (Austrade 2013) together with the democratisation of knowledge will constitute an important role in the educational sector and is predicted to transform universities of the future (Ernst & Young 2012). While theoretical knowledge can be provided through online technologies, experiential hands-on learning will remain a fundamental part of the educational activities in molecular imaging.

As the boundaries between research fields dwindle, transferable skills become increasingly important for the employability of researchers. A recent OECD study (OECD 2012a) reviews the current landscape for researcher training: "An Australian study identified communication, teamwork, and planning and organisational skills as areas for improvements." However, the OECD study points out that there are many understandings of transferable skills, including enterprise skills and cognitive abilities. The OECD report also notes:

"In 2006, only 26% of doctorate holders in Australia were employed as university and vocational education teachers, and only 28% of recent doctorate holders in 2008 were employed in higher education [Commonwealth of Australia, 2011, p. 22]. The rest had found employment in a wide range of other public and private sectors. United States data show that most PhDs work in service occupations, generally professional, scientific and technical services, or in government [Wendler et al., 2010, p. 19]. The share differs by field; PhD recipients in engineering and physical sciences are much more likely to work outside academia than those in social sciences and humanities."

The special attraction of multidisciplinary settings is that they give exposure to different thinking and working styles, and thus support the development of student and workforce attributes that emphasise the importance of problem solving using a broader range of approaches. To the degree that multi- or

trans-disciplinary work is becoming the norm, foundational skills, such as mathematics, physics and chemistry become rather more than less important. It is in this context that nuclear science and technology, with its far reaching utility across many disciplines, is particularly suited to providing a wide range of transferable skills.

Conclusions

We have described the emergence of an inter-institutional partnership that is nested in a network of relationships reflecting different agendas, infrastructure and funding streams. Though both institutional partners are largely publicly funded, they come from different organisational traditions, one being a higher education institution, the other a publicly funded research agency with a specific science and technology mandate.

The Commonwealth's 2006 National Collaborative Research Infrastructure Strategy (NCRIS) was a multi-level national, state and institutional funding mechanism aimed at creating shared infrastructure and capacity while unlocking existing institutional research infrastructure and encouraging new partnerships. As an infrastructure program, it did not prescribe specific scientific content areas.

The ANSTO-BMRI-NIF partnership played out against the backdrop of organisational renewal in both partner institutions. While the BMRI extended the existing university faculty model towards an integrated, mission-oriented research, teaching and social engagement model (centred on mental health priorities), ANSTO broadened the mandate of its research into medical radioisotope activities by forming ANSTO LifeSciences. The latter opened up its infrastructure and associated specific skills for mission-oriented research and thus went beyond a narrower service and technology provider role.

The described partnership has thus sprung from transformational changes within the partner organisations. Both the university as well as ANSTO remain under constraints imposed through their respective funding and business models. Therefore, future management and policy makers at the level of Commonwealth, State and the institution will need to continue to remove inter-institutional barriers, systematically build trust, retain open access, jointly develop educational and career pathways and new research agendas.

From the perspective of a policy maker, our observations suggest that the benefits of public funding are enhanced if directly tied to incentives for partnerships without being over-prescriptive in regard to operational specifics on the ground.

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Invited Discourse: The Invention of the Modern Pendulum Weight Shift Flexwing Hang Glider in 1963

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Abstract

Safe foot launched flight was made possible by the invention of the modern hang glider, controlled by a pendulum weight-shift device. The optimal wing geometry of the hang glider, and correct placement of the pendulum weight-shift device, were determined by trial and error experimentation in natural outdoor conditions. Development of the modern hang glider was based on shop-bought or second hand materials, and did not involve any laboratory-derived data or research funding

Introduction

Figure 1. Water ski kite of the 1960's era.

In January 1963, as a member of The Grafton Water Ski Club, I was approached to design, build and fly, a Water Ski Kite for the upcoming Jacaranda Festival Water Ski Carnival in October/November of that year. This request was made because club members learned that I built and flew a Benson gyro-glider, with rotor blades of my own design. It is worth noting that I found the auto gyro difficult to fly, with sharp control response, I describe as twitchy, with little natural stability. I regard them as very dangerous to fly.

It is now just fifty years since that request was made. The 1950's to 1970's was boom time for water skiing. The rich and famous and those seeking the atmosphere and limelight flocked to any water way, suitable for the activity. Water Ski shows were common. They had competitive events such as slalom, where skiers make dramatic, sharp turns at speed around buoys anchored by rope to the bottom of the river or lake. Trick skiing, ski jumping by skiing up an inclined ramp at high speed, launching into the air and travelling some distance before landing, hopefully, upright on the skis. Other non-competitive events thrilled the crowd such as the "ski ballet", where many attractive young ladies would ski in formation and perform acrobatics. The show would usually end with the main attraction, being the flight of a water ski kite, always seen, as the most dangerous and daring feat. The Grafton Jacaranda Festival Water Ski Show was one of the

biggest in Australia. The riverbank formed a natural amphitheatre. It is an ideal location. The income generated financed the club activities for the next year. Thus the additional attraction of having a water ski kite for the show was a strong motivator for its inclusion.

I had built and flown model aircraft and kites during my childhood years, many of my own design. I was passionate about everything to do with how aircraft fly and all aspects of their design. And, like many model makers, had delved deeply into aerodynamics and structures. At thirteen and fourteen years of age I was reading about aerodynamics and engineering at university level. I had never seen a water ski kite, but had a few photos to go on, and did not consider that the project was going to be a difficult problem. I built what I considered as a representative five sided scale model. It flew quite well, but when a weight was suspended below the kite representing the pilot, it became unstable and the various adjustments and modifications tried, resulted in only minor improvements. Not enough for me to be confident to make an investment in a full sized, person operated device that was in anyway safe to fly. I then considered other kite, or wing-like devices. I was looking for a stable controlled descent as part of the device characteristics, with an angle of descent of 1:1 or 45 degrees.

Previous to the request to build a kite, I had made a model glider based on the flying fox wing. Flying foxes were a common sight around Grafton at that time and I was fascinated by their good glide, the simple structure of their wing and the fact that the wing was flexible, as though it was made of fabric. The model had a good glide, and perhaps a low aspect ratio design based on the fox wing might be an answer to my problem. Even so it would be far more complicated than the simplicity of the water ski kite based airframe, and very expensive.

Figure 2. NASA research para glider wing from the 1960's.

I had discussed my quandary with a number of club members and one member presented me with a magazine that included a photo and article describing an experimental gliding parachute that was being developed by NASA to return space capsules to earth safely under controlled guidance. I saw an exciting possibility that a new gliding device could be created by incorporating the water ski kite airframe into the gliding parachute.

The parachute consisted of two completely flexible semi-conical lobes. I could see that if the nose to tail element of the water ski kite (keel) was secured to the centre section of the gliding parachute, and the cross member (main spar) was installed, bolted to a solid member (leading edge), fitted to each leading edge of the parachute and connected to the keel at the nose, I then had a simple air frame,

that could also incorporate the same lower "U" construction that supports the operator of a water ski kite. Additionally there was a chance that I might attain my "45 degree" parachute like safety descent. There was also recognition of a direct connection in my mind with the bat wing model I had built earlier. The "half semi-cone" shapes of the gliding parachute almost matched the wing tips of my bat model. The low aspect ratio of my bi-conical wing was also seen as a strong possibility of a slow, steep and hopefully stable descent in an emergency. I made the decision to proceed to experiment with models of my concept. I imagined a double lateen sail arrangement as an easy solution to forming my twin semi-cones.

Figure 3. Australian Flying Fox, showing its wings.

Figure 4. Lateen sail – a semi-conical wing, invented by the Egyptians thousands of years ago.

Method

The first step was to design and build models of what I then called "the wing". Air frames were made from timber boxes in which fruit was transported and sold in during the 1960's. The timber was a light soft pine, 6.35mm thick, trimmed down to a square cross section. The centre section length chosen for my model was 500mm. Thus 50mm was 10% of the model length and therefore, easier to apply percentage values, in determining centre of gravity points etc. I called the centre element the "keel". The leading edges were made the same length as the keel, the leading edges were hinged to the keel at the nose, and I used varying lengths for the cross member (main spar) to vary the nose angle. Light brown paper was used as the wing/sail material. I experimented with varying "total" nose angles from 70 degrees to 110 degrees in 5 degree increments. The pattern cut of the sails at the nose angle was 10 degrees more than the frame nose angle. I was surprised at the glide obtained. I found the widest nose angle, 110 degrees, gave the flattest glide. But was less stable laterally and directionally. I settled on 80 degree nose angle with a 90 degree wing sail nose angle, this gave the best all round stability with a better glide than I

required, and I have to admit that I felt some excitement that I was developing a glider capable of real gliding flight. Even so I considered that the drag created by a human body dangling beneath the wing would spoil the glide, and thus I would have my 45 degree decent. However, any sort of a glide would require control to avoid descending into the riverbank, or worse an assembled crowd. I now had a problem of control to solve.

The solution came in a serendipitous manner. I had taken my young daughter to a local park where she loved the swings. I was swinging her backwards and forwards, and sometimes in a circular motion, when it occurred to me that if I were to fit a swing to the "keel" of the wing, and used a fixed bar to work against, then I may achieve three axis control, via the means of weight shift. I reasoned that the frame, usually suspended below the main spar of a water ski kite, could serve this purpose. This meant the overall design and concept of the structure was still heavily influenced by the water ski kite configuration. To test my theory I decided to build a "half sized model" with a wing area of 7 square metres. The nose angle chosen was 70 degrees, which was very stable directionally, and therefore more difficult to move, side to side across the boat wake. The reason for this was that the model was not intended to fly, only to prove if my weight shift concept would work for lateral control, and able to move the wing and skier across the wake, side to side, by aerodynamic effect alone. It was also an opportunity to solve construction problems that may occur with a full sized wing intended to fly.

Rough drawings were made and materials for the construction obtained, mainly from the local tip. The only items purchased were banana plastic sheeting for the sail and electrical sticky tape to seal the lapped joints formed when making the sail. Every other item was obtained from the local tip or the scrap box in my garage.

This test model was trialled in May 1963 on the Clarence River and results were strongly positive. There was sufficient lift to just support the weight of the operator and strong aerodynamic force, developed by the weight shift action, easily moved the wing and skier from side to side across the wake of the ski boat. The tests were conducted at 68kph. Thus pendulum weight shift for aircraft control was a reality.

Figure 5. Half-size model waiting for a test run in 1963. Pilot John Dickenson.

Figure 6. The half-sized model under test. Note that it was never designed to actually fly. Pilot John Dickenson.

Design and construction of the full-sized model

As mentioned earlier funds were short and the risk this experiment may be a complete failure was uppermost in my mind. Therefore, a throw away approach was employed to the selection of materials. For the wing sail blue banana plastic was used as per the half sized model. "Blue Banana Plastic" as it was known, is plastic sheeting 0.001mm thick that is sold in rolls, 0.9m wide, and cut into short lengths by the banana farmers of northern NSW, who wrap the blue plastic sheet around the young bananas to protect them against the strong sun, and cold at night. The blue plastic sheeting could be bought very cheaply. I carried out tests to determine the load the plastic sheet would carry per square metre. A loose sample was taped over the top of a bucket, and dry sand was poured into the plastic sheet which then formed into a dish shape by the weight of the sand. The weight of the sand was equal to 4.5kg applied to an area of 0.093 square metres without any sign of failure. Proving that the plastic sheet sail could safely lift a 725kg flight load, ten times the weight of the pilot and glider. Oregon timber was chosen for the leading edges and centre 38.1mm x 38.1mm square, with chamfered corners, straight grained no warps, no knots. It also had the advantage in it would allow the wing to float.

The blue plastic sheeting was cut into suitable lengths, then overlapped directionally wing tip to wing tip, and secured together with blue electrical sticky tape. The excess was cut away to form a "sail" of sufficient area to form the bi-conical wing. The sail was attached to the timber leading edges and keel using rounded timber strips nailed in place with 25mm steel brads.

The main spar was 3.048m long, 38.1mm outside diameter, TV antenna mast quality aluminium tube, with a wall thickness was of 1.6mm. It was short of the length I required, but it was all that was available at the time. Turned hardwood dowels were fitted and glued into the main spar tube at the centre connection, and at each end to provide sufficient strength at these points.

The straining wires were as per TV antenna mounting, more than 10 times the estimated strength required in flight, lowest cost and readily available.

6.35mm diameter hardware store quality cad plated hexagon bolts, were used at airframe joining points, much stronger than expected flight loads. 6.35mm shaft thickness 'D' shackles, connected the flying wires to the control bar mounting points, which were 5mm thick steel tabs welded to the control bar. The total cost of all components then, was $24.00.

Selection of the sail area was based on the idea that a 1:1 descent angle was possible, a parachute-like descent in full stall. The area of parachutes is typically 16.3 square meters. 14.9 square meters area was chosen since, hopefully, any such emergency descent would be into water and a higher descent rate than a parachute would be acceptable and still provide a safe landing.

The timber components were subjected to strength tests by hanging them from a beam in the garage, and suspending weights from them equivalent to ten times of the total load the component was to carry. It was shown in a crash during test flights that the wing was a lot stronger than pre-flight structural testing.

Establishing control

A relationship between the pilot, control bar movement, and angle wing attack needed to be worked out. The pilot would be suspended at the centre of aerodynamic lift. Tilting the nose down would effectively shift the pilot's weight forward, this was accomplished by moving the control bar rearwards towards the pilot's stomach, thus causing the wing to dive, and moving it away from the pilot, would induce a climb. It would also, at maximum movement away from the pilot, and if the relationship was correct, enter a controlled stall, with the desired 45 degree descent. Conventional aircraft wings generally operate angles of attack between 2 degrees to 16 degrees, with best average cruise angles of 8 degrees. The very extreme washout of my wing made it difficult to determine the average "desired" angle of attack of the wing, of around 8 degrees. By using the maximum movement my hand could reach outwards from my stomach, I measured 61cm. I decided on a wing tilt of 22 degrees, to give me the full control into deep stall I was looking for. A little simple trigonometry gave me a nominal lever length of (152.4cm). The control bar was given a length of 106cm and outside diameter of 30mm. Dimensions were determined as a result of the practical experience with ½ sized model test. Hessian straps were attached to a timber board 152cm long x 25cm wide to form the seat and suspension from the keel to the seat. The seat was hung so that it was 38cm below the control bar when the seat straps were forward against the control bar. This means that minimum angle of attack of the wing occurred, when the control bar was pulled back against the straps, and would be in maximum dive. A guesstimate was made, based along the line formed along the top of the sail looking at the side view, from the nose to the trailing edge of the sail, as being the zero angle of attack. The components of the wing were assembled and the wing made ready for testing. As it turned out, the angle of attack estimate was a very serious error.

The first test flights:
Saturday afternoon 7th September, 1963

The wing was pre-assembled and checked, prior to transport to the beach adjoining the Water Ski Club on the Clarence River at Grafton. The weather was cool, but fine, with a light southerly breeze. At the beach, the wing was reassembled and made ready for testing.

The wing was connected to 42.8m of ski rope, two, 21.4m lengths, normally used by water skiers. If flight was achieved it was intended to limit the maximum height attained around 9m to 12m, by varying the boat speed.

Figure 7. John Dickenson taxis out to take off, and make his second attempt at a successful flight with the full-sized Mark 1.

I made the first attempt with seat connected to the most forward centre of gravity point at 45% of keel length from the nose of the wing, two other connection points were set at 47.5% and 50% of keel length, tests on the 80 degree nose angle model showed 47.5% as the average centre of gravity.


Figure 8. First successful flight of the Mark 1 under full control.

A satisfactory start was made and the wing settled above me, and despite every attempt to attain a positive angle of attack, the wing just fluttered, without any sign of lift at all. I was carrying the full weight of the wing, 20 – 23kg. I returned to the beach utterly exhausted. Since at that time my prowess as a water skier was 'C' grade, it was thought that a more competent skier may have better success, and do a better job of placing real weight on the swing seat, thus inducing an angle of attack, and hopefully flight.

Our following test pilot, Norm Stamford, made the next attempt with exactly the same result, no sign of lift at all.

Test pilot number three was much taller and heavier than the earlier would be test pilots, but, in view of the total lack of lift on the first trial runs, the seat was moved to the rearward mounting point. All was made ready, the boat accelerated, the jump start affected, and our pilot shot up 24 metres. The pilot pulled the control bar as far back as he could, the boat stopped dead at the same instant, and test pilot number three plunged straight down 24 metres. He was not physically injured, but severely shaken. The wing proved its strength and was undamaged.

The wing was made ready again and our fourth potential pilot prepared for flight. The seat suspension point was moved to the central mounting point at 47.5% of keel length. Rod Fuller, our Club's top skier and district champion, made an easy jump start, settled into the seat, the wing was carrying his weight easily. The boat was accelerated into the breeze and the wing climbed steadily into the air. It continued to climb to an altitude limited by the length of the rope, i.e. 42.8m. Regrettably the control bar was set too far rearward and Rod could not pull the wing down, and the wing was flying close to stall. Fortunately the boat driver, Patrick Crowe, realised what was occurring and managed to swing the boat in a wide curve and gently lower Rod back to the water by running down wind, necessary to keep the boat on 'plane'. Rod and the wing were returned safely to shore. Following discussion with Rod, I replaced the fore-aft wires and reset the control bar forward, which effectively reset the angle of attack of the wing.

For the second time I made an attempt to get the wing into the air under full control. This second attempt was a complete success. Once settled into the seat, which I found very comfortable, the take off was easy and I had full control of the wing. The flight varied between a maximum altitude of 16 metres, and down to 4 metres. Pitch and lateral (turn) control was excellent, the wing was a delight to fly, and perfectly stable on every axis. I also found that the wing was gliding on a slack rope, a glide that was flatter than anticipated, and I realised, while in the air, that I had developed a new form of glider with the potential for foot launched gliding flight. The flight was not timed exactly but was 20 to 30 minutes. I packed up my wing, loaded it on the car, very pleased and excited, the other club members equally so. Additionally we had our big attraction for the

upcoming Jacaranda Water Ski Carnival. Within days I had lodged a patent application, entitled, "An Improved Gliding Apparatus". Patent pending No. 36819/63 was granted, dated 11th October, 1963. I called my new flying machine the "Ski Wing".

To establish an effective research program to develop and fly the wing, it was necessary to devise procedures for take-off, during flight, landing and ground handling. Additionally, following the successful test flight, two important matters required attention:

1. Review of the wing structure as exposed by flight experience.

2. Learning to fly the wing with its totally new form of pendulum weight shift control.

Structural modification

During following flights it was found that the keel was flexing in response to varying flight loads.

A simple modification solved the keel flexing problem. The control bar had a metal tube strut welded at each end, and were bolted to the main spar and leading edges. The ends of the struts were moved to the centre of the main spar, thus forming a triangular structure which I called the "A" frame. A wire was connected from each end of the base of the "A" frame (the control bar) to the ends of the main spar thus forming an immensely strong system to carry the flight loads.

The pilot suspension point was moved backwards and forwards from the initial test flight setting, to obtain the optimum location, and it was found that the initial setting was best at 47.5% of keel length from the nose of the wing.

No other structural changes were made to the wing prior to its debut at the Jacaranda Water Ski Carnival.


The Daily Examiner
Carnival
A. Explains
hy There Is
Be Election
HE'S AIRBORNE ABOVE THE CLARENCE RIVER WITH A SKI WING
Still Searching
For Whaler
DEFENCE SPENDING
BY LABOR GOVT.
Relationship With
Australia Harmed

Figure 9. The report of the ski wing in action at the Jacaranda Water Ski Carnival that appeared in the Daily Examiner, Grafton, 21 October 1963.

Process of controlling the wing, take off, flight and landing

During one of the many flights leading up to the carnival I lost my ski while taxiing at speed behind the boat (we only used one ski and employed a jump start). I was dragged underwater for some distance. As a result I designed and constructed a release mechanism that was fitted to the boat the following weekend. The release was employed for every flight from then on until we ceased flying at Grafton in November 1965.

It was essential to establish a routine of understanding between the pilot, observer and boat driver. It was particularly important for the observer to communicate the instructions clearly to the boat driver. The pilot nodded his head up and down for more speed, and horizontally for less speed. The boat driver would indicate his intentions to the pilot directly with hand signals.

Figure 10. Rod Fuller shows off the wing with the "A" Frame modification, October 1963.

Transition: ski wing to hang glider

Although it was obvious from the first successful flight that the wing as flown, was suitable for foot launched soaring flight, I realised that there was an opportunity to fully develop the wing and methods of launch and flight control, with great safety over water in towed flight. Additionally we could climb to height and release into gliding flight, perform manoeuvres, and develop non-towed landings.

There was a problem. The wing, now called the "Mark 1" flew too slowly to allow full testing behind a speedboat. I needed a wing that would take off at 40 kph when the boat was up and planing. The Mark 1 wing would often take off when the boat was hardly moving. As a consequence, in January 1964, I built a smaller wing Mark 2 with 4.27m long leading edges and keel. The construction was all aluminium airframe, but I retained the banana plastic wing sails and, with a release system to disconnect the glider from the tow rope, which was fitted to all following gliders built, thus allowing free gliding flight.

Figure 11. Release mechanism fitted to the ski boat rope attachment point to disconnect the Ski Wing in an emergency. Used from October 1963 to December 1965.

After very few flights, the banana plastic sail that had been attached to the metal airframe with contact adhesive, started to de-laminate. The Mark 2 also flew too slowly to suit my testing plan, so the Mark 2 was scrapped. In February 1964 I completed Mark 3, consisting of 4m timber leading edges and keel. The cross section of the timber was as per the earlier Mark 1, 'A' frame dimensions as per the Mark 1, release system, and a design change to a fully folding air frame and "A" frame, allowing easy transport and rapid assembly and re-packing.

The Mark 3 matched the boat speeds perfectly, was easy to fly and immensely strong.

Take-off air speed	37 – 40 kph.
Stall speed	32 – 35 kph.
Maximum speed	75 kph.

Figure 12. Amy Dickenson displays the fold ability of the Sky Wing. The wing was constructed to aircraft standards in late 1964.

Figure 13. The Mark 3 in gliding flight in early 1965. Pilot Rod Fuller.

However, despite my estimated maximum airspeed, on one flight, at a Water Ski Show, I found myself being towed by a maniac boat driver and I estimate the 'air' speed into the prevailing wind as "at least" 110kph.

Figure 14. Botany Bay record endurance flight attempt for towed flight of 6 hours, April 1969.

Over time, as finances would permit, the Mark 3 design was up graded to aircraft engineering standards, with aluminium airframe, nylon sail fabric, and stainless steel flying wires, bolts and fittings. Battens were fitted in the wing trailing edges to prevent flutter. By adding battens to the trailing edges of the wing sail and making a scalloped curve of 6% of the width between the battens, a noticeably flatter glide, with increased speed due to the lower drag, was achieved. By the beginning of 1965, the fully developed Mark 3, scaled up to the size of the original Mark 1 was the template for the Standard Hang Glider for more than the next ten years, and is known today as the "Dickenson Wing".

Fifty years later most hang gliders still employ the same basic five element air frame namely, keel, main spar, leading edges, "A" frame and the essential Pendulum weight shift control.
Powered Micro-light aircraft development was initiated by adding an engine and seat to the bi-conical "Dickenson Wing" with pendulum weight shift control. In October 2012 I was awarded the "Federation Aeronautique Internationale" "Gold Air Medal". Regarded as aviation's highest honour, the sponsors of the award successfully claimed that more people have

learned to fly with the "Dickenson Wing" than any other type of aircraft in the history of flight.

John and Helen Dickenson

(First draft of manuscript received 26 February 2013; final manuscript accepted 12 June 2013.)

John and Helen Dickenson John Dickenson has had a diverse career as an engineer, involved in a many wide-ranging projects, such as the pioneering radio telescopes built near Badgerys Creek in the early days of radio astronomy. He has received numerous awards for his contributions to aviation, most notably the Federation Aeronautique International (FAI) Gold Air Medal in 2011, together with a Presidential Citation from the United States Hang Gliding and Paragliding Association and the Oswald Gold Medal for the most notable contribution to aviation by an Australian by the Royal Federation of Aero Clubs of Australia. He was awarded an Order of Australia (OAM) Medal in the Queen's Birthday Honours of June 1996. His daughter, Helen, has a BA from Sydney University and a MA from Macquarie University.

John Dickenson
Image by Evan Okland from the Ken de Russy collection.

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Invited Discourse: The humanist paradox

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Abstract

This article is based on a lecture that the President of the Royal Society of New South Wales was invited to deliver at Warrane College, University New South Wales on Wednesday, 17 April 2013. It examines the impact of humanism, perhaps the most influential social movement of the last half millennium. A number of problems with the humanist approach are identified and emphasises the need to encourage to "Renaissance thinkers" who can engage across all disciplines of science, art, literature and philosophy so that a wide range of perspectives and worldviews can be engaged to solve the unprecedented problems of the 21st century. The Royal Society of NSW can provide a forum for Renaissance thought.

Keywords: humanism; Renaissance thinkers; two cultures;

Introduction

"*We live amidst the ruins of the great, 500-year-epoch of humanism. Around us is that 'colossal wreck'. Our culture is a flat expanse of rubble. It hardly offers shelter from a mild cosmic breeze, never mind one of those icy gales that regularly turn up to rip us out of the cosy intimacy of our daily lives and confront us with oblivion. Is it surprising that we are rundown? We are desperate, yet don't care much anymore. We are timid, yet we cannot be shocked. We are inert underneath our busyness. We are destitute in our plenty. We are homeless in our own homes.*

What should be there to hold our hand is not. Our culture has absented itself. It has left us terribly alone."

Thus starts "Humanism: the wreck of Western culture", by John Carroll (2004). The philosophical position now known as humanism is said to be based on two premises: that there are no supernatural agencies in the universe and that our ethics ought to be based upon and respond to human experience (Grayling, 2013). Humanism originated in Italy in the 13th and 14th centuries. It was founded on the view that much could be learnt human thought but was far from the modern position that there is no supernatural being. Rather, the belief was that God was the creator and supreme authority, having created the universe according to some general rules that are discoverable by mankind. It was not until the 19th century that humanism acquired its modern association with agnosticism or atheism. In particular, early humanism emphasised learning from pre-Christian Greek and Roman sources, to inform pursuits such as political science and government. This was a key influence on the Renaissance and the subsequent emergence of science and our so-called "modern" or "modernist" era.

Some have said that humanism placed mankind at the centre of existence, rather than God.

Over the next few hundred years, the Renaissance flourished, the agricultural, scientific and industrial revolutions took place, first in Britain in the 17th and 18th centuries, in the 19th century extending to Europe, then, in the late 19th and early 20th centuries, to the US. Later still, after 40 years of appalling world-war and economic depression, it spread to Japan and, in the last twenty years, has reached the developing countries of the world.

Given the extraordinary progress over the last 500 years, it is difficult to argue that in purely material terms, humanity is not better off. For example, at the start of the 20th century, life-expectancy at birth in Australia was 55 years for a woman and 51 for a man. Today, it is 84 years for a woman and 79 for a man – your children can expect to live a good thirty years longer than your grandparents. Many diseases that cut swathes through mankind for thousands of years have been eliminated. In Australia, we live in unprecedented comfort, even luxury. We have excess. Even in so-called undeveloped countries, obesity is becoming a major problem. We all look forward to next year's iPhone, the latest model of BMW and next season's designer clothes.

Nearly all of this material progress has been as a consequence of science and its application. For the last 150 years, as soon as new scientific knowledge was discovered, technologists, doctors and engineers were finding ways to use it to solve long-standing problems. The first big advances were just cleaning up the consequences of industrialisation – building sewers and providing clean water. Electricity replaced steam and with electricity came radio, electronics, and ultimately computer technology. This gave us the means to build and control ever more complex things – ships, oil refineries, aeroplanes, bombs and guided missiles. These developments were on multiple fronts – within a few years of Pasteur proposing the germ theory of disease, ways to deal with microbes were already being tested. First, sulfa drugs, then penicillin and a vast array of other synthetic materials were developed that largely controlled infectious disease. Even human behaviour has been subjected to the scientific method – from psychology to sociology and even the "dismal science" (as Thomas Carlyle called it) of economics. All this has meant that human knowledge has become very complex and few if any people have a comprehensive understanding across it all.

All this progress was not universally good. Mistakes were made and some of them were very serious. Early aeroplanes crashed with catastrophic regularity [35]. Pharmaceuticals, despite their enormous benefit also caused great tragedies from time-to-time [36] Industrialisation has caused widespread environmental degradation and species loss is now taking place at a rate that is at least as rapid as the three or four major extinction events in the geological record.

From the outset there were those who are not comfortable with the direction that Western civilisation was taking. As early as the 18th century, environmentalists such as Poivre were concerned about the damage being done to forests and natural systems. By the late 18th and 19th centuries the indifference and

[35] For example, the Hawker de Havilland Comet that broke up in mid-flight due to catastrophic failure caused by metal fatigue.

[36] Such as the thalidomide case that caused thousands of birth defects when prescribed to pregnant mothers.

cruelty of the new industrial order, with its child labour, excessive working hours, low pay and slum housing began to stimulate the collective social conscience, leading to gradual legal reform. This era was one of great extremes: on one hand, there was enormous economic progress and the development of modern institutions; on the other, was urban poverty, social dislocation and widespread perceptions of loosening of moral standards.

But the shock of two world-wars and the Great Depression in the first half of the 20th century forced unprecedented change on the world. The rebuilding necessary in Europe and Japan in the second half of the century gave an enormous boost to economic growth and the opportunity for further modernisation and for science, technology and economic rationalism to become dominant.

It is interesting to note that although these advances took place in many countries, there were a few that led the way. In general, these were countries with relatively open, free-market, capitalist economies and socio-political systems that have been fundamentally liberal. The combination of liberalism, laissez-faire economics (based on free-market capitalism that focuses on consumption) and socio-political systems with fundamentally strong institutions have shaped modern civilisation. It has become a rationalist system that focuses on the material satisfaction of the individual. After a gargantuan sixty-year struggle, socialism collapsed in the early 1990s, reform took hold in Russia, Eastern Europe and China and now most countries have some form of consumption-led capitalism. Even totalitarian regimes have substantially liberalised their social systems.

If humanism shifted focus from God to mankind, liberalism completed the task – it placed the individual firmly at the centre of modern society.

Paradoxically, this progress, the product of humanism, has dehumanised us. Even in the areas of human knowledge outside science and technology, concentration of expertise keeps the broader populace at a distance. It is harder to engage. It has driven out the spiritual. It has provided us with false comfort. There have been movements against modernism – for example, post-modernists or, more accurately anti-modernists who, as the noted German cultural theorist, Jurgen Habermas (1981) put it, seek to return to the archaic notions of imagination and emotion. Some of those who have been excluded because of their conflicting worldviews have become fundamentalists, extremists or even terrorists. Wealthy societies are still plagued with inequality and social problems such as drug addiction, homelessness and broken families. The social dislocation of the 19th century is still manifested, just in different forms.

Ought we conclude that there should be an end to free-market capitalism and the liberal existence that we value so highly in Australia? No, not all. Despite its deficiencies, the good far outweighs the harm. Does it mean that we should abandon the humanist approach? No, not all. The problem is not with the concept of humanism – rather, it is our over-emphasis of rationalism and liberalism. Rationalism, whether it is in its application to science, technology or economics excludes or marginalises matters of belief, values and differences in worldview. Liberalism makes us selfish and narcissistic. It discourages the obligations that we all have as family members and as citizens.

So why is this important? Is Professor Carroll's bleak image our destiny?

In the last 20 years or so, the world has reached a point that has never been seen before. Scientific and technological progress has been so great that our actions are now starting to have a profound impact on the natural world. As recently as 50 years ago, this was not the case – our impact was largely localised or regional. This was because the consequences of human activity (such as deforestation, carbon dioxide emissions, water pollution, and so on) were relatively small in comparison to the flows circulating in the natural world. A striking example is carbon emissions. Since about 1750, which is when the industrial revolution began, it is estimated that 355 billion tonnes of carbon have been released to the atmosphere through burning fossil fuels and making cement. Over half of this – about 200 billion tonnes – has been emitted since 1980 (Boden, 2012). This has caused the CO_2 concentration in the atmosphere to rise by nearly 40% since 1750. Now there are some who say that this may not be due to burning fossil fuels – it might just be the natural order of things. But this fails the common-sense test. Consider the example of the burning of coal: most commercially viable black coal deposits were formed in the Carboniferous and Permian periods of 250 million years to 350 million years ago when bark-bearing trees first evolved. As the trees died, they were gradually covered over due to later geological activity, compressed and heated, ultimately forming black coal. It takes tens of millions of years for a substantial coal deposit to form. According to BP, an energy company, there are about 112 years' of proven coal reserves remaining at current usage rates (BP, 2012). Unproven reserves are perhaps double this or even more. But the point is that in a period of about 500 years, industrial production will return to the atmosphere carbon that was captured over a period of about 100 million years. Is it surprising that atmospheric CO_2 concentration is increasing? There other examples of similar problems – methane from rotting vegetation due to deforestation and farming ruminant animals, nitrous oxide from combustion, CFCs from synthetic refrigerants and many others.

The problems that must be faced in this century in many respects are far more serious than those faced by any other generation of humanity. On one hand, it does not seem reasonable to deny undeveloped countries the material benefits that developed countries now possess; on the other, almost certainly there are not enough resources in the world for this to happen without catastrophic, intractable damage. Something has to change.

The fundamental challenge at the heart of this is that the problems we now face are not the sorts of problems that will readily yield to the rationalist approach. They are highly complex. They are as much about social systems and value systems as they are about technology. Applying the rationalist methodology simply does not work. Why? Because most of the issues have deeply entwined values associated with them. They can be of all sorts – religious, social, cultural, environmental – but they largely depend on the beliefs and worldviews of the people engaged in the problem. Solutions to these problems are essential if our civilisation is to be sustainable in the long term. Species loss, climate change, environmental pressures from urbanisation, overstressed water resources, chronic disease, pandemics, destruction of ecosystems and loss of the natural world – the list is a long one.

Consider again the example of climate change. There is an overwhelming body of rationally-determined, scientific evidence that suggests that the emission of greenhouse gases is having a profound effect on the world's climate. Yet there are those who set all this aside saying that the climate changes anyway. Well, yes it does – almost no-one disagrees with that. But even if there is a only a small chance that the scientific evidence is correct, it is entirely irrational not to take steps to reduce emissions because of the profound consequences that follow should the scientific evidence be right. The discourse becomes emotionally charged because of largely irreconcilable worldviews and vested interests. Scientists need to find new ways to engage and to explain the problem to non-scientists.

But what does this have to do with Royal Society of NSW? A curious incident from the 1950s might make this clear.

In a talk that he gave at Oxford in 1959, entitled "The two cultures", a distinguished British civil servant, C.P. Snow (1959), argued that intellectual life in Britain had polarised to the extent that there were now two distinct cultures: one that had formed around the humanities and the other that was based on science. Snow was both a scientist – he had a PhD in spectroscopy from Cambridge and occupied high-level administrative posts during the Second World War – and a successful novelist, so he had considerable insight into both camps.

These two groups were finding it more and more difficult to find common ground and to communicate with each another. Disturbingly, according to Snow, this was becoming a serious impediment to addressing the major problems in the world. He was particularly critical of science education in Britain for not preparing non-scientists to understand and accept scientific argument. To Snow's great surprise, his lecture became particularly controversial. He was attacked intellectually and was personally vilified. Some argued that he was pressing to have the world run by scientists. Others said that he was too utilitarian and neglecting the importance of the humanities.

Snow's concerns were prescient. Today, scientists and technologists face a bigger challenge than ever in communicating with people who do not have a scientific background. Indeed, the situation is far more serious than in Snow's time because of the critical challenges the world faces. There are really only two choices to deal with these: try to resolve them through the application of science and technology in its broadest sense to reduce the impact on the ecosystem; or risk the collapse of our civilisation and Carroll's scenario becomes true.

But, as noted above, when scientists try to communicate information behind a complex issue like climate change, there is a predictable, irrational backlash that denies the established science.

So what can be done about it? The towering figures of the Renaissance – Petrarch, Galileo, Michelangelo, Dante, to name but a few – were humanists but all were deeply religious and saw human creation as an expression of their faith rather than a celebration of humanity. The Renaissance was so productive because the combination of science, art, literature and philosophy provided enormous stimulus. Science informs us about what we know. The scientific method is, to date, the best means we have for establishing rational, objective knowledge. Yes, it has its limitations and we need to be aware of these but it is better than

any other system that mankind has so far devised. Art shows us new ways to look at things, new ways of seeing. An interest in art gives us fresh ways of interpretation. Literature gives us the capacity to communicate, to create rich narratives which, if framed around objective knowledge, can be a powerful means to engage with and convince others of the soundness of our arguments. And philosophy, in some respects, is the most important of all. As Bertrand Russell (1946) put it, it gives us the means to bridge the no-man's land between knowledge and theology. It gives us the means to understand different belief systems and to engage with them.

Today, more than ever, we need "Renaissance thinkers". We need to have a lively appreciation of things outside our own professional expertise across the domains of science, art, literature and philosophy. The foundational rules of the Royal Society of NSW call for just that – it exists to "encourage studies and investigations in science, art, literature and philosophy" – its purpose is to keep Renaissance thinking alive.

Historically, the Society has focussed much of its attention on science. This is not surprising given the importance of technology development in Australia in the last 20 years. But the time has come for us to broaden our activities and return tour our original Renaissance purpose. The Society has a valuable role to play in providing a forum for the discussion of ideas and issues across all disciplines and to provide a meeting-place to exchange views and to resolve differences in world-view.

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Thesis abstract

Experimental investigation of high frequency combustion instability in cryogenic oxygen-hydrogen rocket engines

Justin Steven Hardi

Abstract of a thesis for a Doctorate of Philosophy submitted to The University of Adelaide, Adelaide, Australia

Self-sustaining pressure oscillations in the combustion chamber, or combustion instability, is a commonly encountered and potentially damaging phenomenon in liquid propellant rocket engines (LPREs). In the high-frequency variety of combustion instability, the pressure oscillations take on the form and frequency of an acoustic resonance mode of the combustion chamber volume. The most common mode in naturally occurring instability, and also the most destructive, is the first tangential mode, with acoustic gas oscillations oriented transversally to the direction of propellant injection. The instability is driven by the coupling between acoustic oscillations and unsteady energy release from combustion. The mechanisms through which injection and combustion firstly respond to the acoustic field, and secondly feed energy back into the acoustic field have not yet been fully characterised.

Shear coaxial-type injectors are common in LPREs. Past experimental and numerical research efforts have investigated the interaction between this type of injector and transverse acoustic fields. Some experimental efforts have successfully forced transverse acoustic modes and studied their influence on shear coaxial injection under LPRE-like conditions. Acoustic forcing of coaxially injected LOx/H_2 has previously been conducted only at low pressures and injection performance levels. This work addresses the lack of experimental data available for the interaction of shear coaxial injection of LOx/H_2 with acoustics under conditions representative of industrial engines.

A new experimental rocket combustor, designated 'BKH', was developed for investigating the response of a reacting spray of coaxially injected LOx/H_2 to an acoustic field. For characterising the response, simultaneous high-speed recordings of both backlit shadowgraph and hydroxyl radical (OH*) chemiluminescence imaging have been captured through optical access windows. The operating conditions of BKH extend to conditions more representative of actual LPREs than has previously been achieved with LOx/H_2 in studies of flame-acoustic interaction. BKH was run at pressures of 40 or 60 bar, which correspond to subcritical and supercritical thermo-physical regimes for oxygen. Hydrogen injection temperature was ambient, around 290 K, or cryogenic, around 50 K. An array of multiple injectors was used to better represent real engines. A system for modulating the nozzle exhaust flow was used to induce acoustic perturbations inside the combustion chamber. Two types of perturbation were

applied to the near-injection region; oscillating acoustic pressure, and oscillating transverse acoustic velocity.

BKH was used to investigate how subcritical or supercritical pressure level and ambient or cryogenic hydrogen injection temperature influence the interaction of acoustic pressure or velocity with injection and combustion processes. Shadowgraph imaging reveals up to 70% reduction in the length of the oxygen jet when subjected to acoustic velocity of amplitude approaching that of the hydrogen injection velocity. Furthermore, the mode of jet breakup changes from its natural growth-and-detachment behaviour to a 'transverse stripping' mechanism. OH* imaging reveals a corresponding decrease in the extent of the flame, and increase in emission intensity. When subjected to acoustic pressure, OH* emission from the flame was observed to fluctuate in phase with pressure. Thus, responses to both acoustic pressure and velocity have been observed in BKH, which together may form the basis of a coupling mechanism for driving natural combustion instability in LPREs.

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Thesis abstract

The ecology and biology of stingrays (*Dasyatidae*) at Ningaloo Reef, Western Australia

Owen R. O'Shea

Abstract of a thesis for a Doctorate of Philosophy submitted to Murdoch University, Perth, Australia

Batoids make up a significant portion of the biomass in coastal and nearshore ecosystems, yet few data are available on the functional role and life history characteristics of rays in these environments. Given their conservative life history traits and vulnerability to extrinsic pressures, urgent information is required to further understand this little known group of fishes. The objectives of this research were to assess the biological and ecological characteristics of tropical stingrays at Ningaloo Reef, Western Australia. More specifically, I wanted to quantify the physical and biological impacts associated with predation by stingrays, prey specificity and trophic resource partitioning and age and growth of five sympatric species: blue-spotted mask *Neotrygon kuhlii* (Müller & Henle 1841), cowtail *Pastinachus atrus* (Macleay 1883), blue-spotted fantail *Taeniura lymma* (Forsskål 1775), porcupine *Urogymnus asperrimus*, (Bloch & Schneider 1801) rays and the reticulate whipray *Himantura uarnak* (Forsskål 1775).

A technical assessment for safe and ethical lethal sampling protocols for large dasyatid rays is discussed as a foundation to this research. Strict codes of practice for the welfare of animals in scientific research demand up to date methodologies for ethical consideration, especially where death is an endpoint. Safe and humane techniques were developed as part of this study in order to sample the rays required using lethal methods. These techniques proved successful with both considerations met and it is hoped, will provide a framework for safe practices for any future work where lethal sampling of large, potentially hazardous demersal elasmobranchs is required (O'Shea et al. 2013).

Age and growth parameter estimates were evaluated for these five species by sectioning and counting calcium band-pair deposition in vertebral samples. Due to less than ideal sample sizes on account of logistical constraints, a multi-analytical approach was adopted to optimise parameter estimates and generate realistic results. This included using a Bayesian framework to approximate the posterior distribution of the growth parameters. Growth rates of smaller-bodied species were faster than for larger-bodied species, but longevity was shorter. The oldest recorded age for these rays was 27 years and although validation was not possible, annual deposition is assumed based on previous accounts of similar species. This is the first time that growth parameter estimates in dasyatid rays have been assessed using this approach, yet the

application is highly relevant for other rare, vulnerable or endangered species where optimal sample sizes may not be possible (O'Shea et al. in review).

The characterisation of ray diets was assessed through stomach content analysis from 170 individuals of these five species. Five broad taxonomic prey categories were common to all species of ray; however, *H. uarnak* is shown to be a crustacean specialist while the remaining four species showed high levels of overlap within their diets (O'Shea et al. 2013). Assessment of the physical impacts related to stingray foraging within an intertidal embayment, previously identified as an area of intense feeding by rays, demonstrated high levels of sediment excavation. As a direct result of bioturbation by stingrays over 21 days, 760 kg of sediment was excavated from an experimental area of 1,500 m^2 (O'Shea et al. 2012). Predation effects by rays were examined by experimentally manipulating densities in fixed areas to prevent feeding. Results indicated that some, but not all prey-taxa differed significantly in abundance between treatment and controls. Sampling also allowed a quantitative assessment of infaunal taxa common within the Marine Park, and the potential importance as a prey source for rays, as well as other epibenthic predators.

Throughout the course of this study, a new species locality record and parasite-host relationships was described for the parasitic leech *Pterobdella amara* and *Himantura leoparda* and *Urogymnus asperrimus*. This is the first time this leech has been encountered in Western Australia and in combination with a significant gnathiid isopod larvae infestation; the effects on an individual stingray are documented (O'Shea 2010).

A methods paper is also included in this thesis detailing a cost-effective method of tag attachment and retrieval for short-term tracking in reef associated elasmobranchs. Field-testing of galvanic timed releases and the practical application in tagging two individual black tip reef sharks (*Carcharhinus melanopterus*), two large cowtail stingrays (*Pastinachus atrus* and a single porcupine ray *Urogymnus asperrimus*) are discussed. Preliminary results of these short-term tracks demonstrated that these methods are a rapid and effective means of tagging elasmobranchs with limited impact on the animal's welfare (Speed et al. 2013).

This research is the first of its kind at Ningaloo Reef and details critical functional processes and highlights the ecological significance of rays within coral reef environments. It also details current methodologies and techniques trialled for the first time within the context of ecological studies on tropical elasmobranchs. Data presented here can be used to develop or contribute to, conservation and management strategies for this overlooked, yet vulnerable group of fishes.

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The Royal Society of New South Wales

The Clarke Medal 2013

The Clarke Medal was established to acknowledge the contribution by the Rev William Branwhite Clarke MA FRS FGS, Vice-President of the Royal Society of New South Wales from 1866 to 1878 The Medal is awarded annually for distinguished work in a natural science done in Australia and its Territories.

The Medal is awarded by rotation in the fields of geology, botany and zoology. This year's award is in the field of geology in all its aspects. Nominations are called for the names of suitable persons who have contributed significantly to this science.

Nominations should include a list of publications, a full curriculum vitae and a statement clearly indicating which part of the nominee's work was done in Australia and which part was done overseas.

The winner will be expected to write a review paper of their work for submission to the Society's Journal and Proceedings.

In cases where the Council of the Society is unable to distinguish between two persons of equal merit, preference will be given to a Member of the Society.

Agreement of the nominee must be obtained by the nominator before submission and included with the nomination.

Only electronic submissions will be accepted. Nominations and supporting material must be submitted to the Honorary Secretary at secretary@royalsoc.org.au no later than **30 September 2013**.

The winner will be announced and the Medal presented at the Annual Dinner of the Royal Society scheduled to be held in 2013. The winner will be notified at least two weeks beforehand.

The James Cook Medal

The James Cook Medal was established in 1947 with funding by Henry Ferdinand Halloran. Halloran, who had joined the Society in 1892 as a 23 year-old, was a surveyor, engineer and town planner. He did not publish anything in the Society's Journal but he was a very enthusiastic supporter of research. Halloran funded what were to become the Society's two most prestigious awards, the James Cook Medal and the Edgeworth David Medal, the latter being the medal for young scientists.

The James Cook Medal is awarded at intervals for outstanding contributions to science and human welfare in and for the Southern Hemisphere.

Agreement of the nominee must be obtained by the nominator before submission and included with the nomination.

The winner will be expected to write a review paper of their work for submission to the Society's Journal and Proceedings.

Only electronic submissions will be accepted. Nominations and supporting material must be submitted to the Honorary Secretary at secretary@royalsoc.org.au no later than **30 September 2013**.

Should the Medal be awarded, the winner will be announced and the Medal presented at the Annual Dinner of the Royal Society of NSW to be held in 2014.

Walter Burfitt Prize 2013

The Walter Burfitt Prize was established as a result of a generous gift to the Society by Dr W.F. Burfitt BA MB ChM BSc of Sydney, which was augmented by another gift from Mrs W.F. Burfitt when Dr Burfitt died in 1957. The Prize was further augmented in 2004 by a gift from Dr Burfitt's grand-daughter Mrs A. Thoeming.

The Prize is awarded at intervals of three years to a worker in pure or applied science, resident in Australia or New Zealand, and whose papers and other contributions published during the past six years are deemed of the highest scientific merit. Account is taken only of investigations described for the first time, and carried out by the author mainly in these countries.

Nominations should include a list of publications, a full curriculum vitae and a statement clearly indicating which part of the nominee's work was done in Australia or New Zealand and which part was elsewhere.

The winner will be expected to write a review paper of their work for submission to the Society's Journal and Proceedings.

In cases where the Council of the Society is unable to distinguish between two persons of equal merit, preference will be given to a Member of the Society.

Agreement of the nominee must be obtained by the nominator before submission and included with the nomination.

Only electronic submissions will be accepted. Nominations and supporting material must be submitted to the Honorary Secretary at secretary@royalsoc.org.au no later than **30 September 2013**.

The winner will be announced and the Medal presented at the Annual Dinner of the Royal Society scheduled to be held in 2014. The winner will be notified at least two weeks beforehand.

The Edgeworth David Medal 2013

The Edgeworth David Medal, established in memory of Professor Sir Tannatt William Edgeworth David FRS, a past President of the Society, is awarded for distinguished contributions by a young scientist.

The conditions of the award of the Medal are:

- The recipient must be under the age of thirty-five years at 1st January, 2012.
- The Medal will awarded be for work done mainly in Australia or its Territories or contributing to the advancement of Australian science.

Nominations are called for the names of suitable persons who have contributed significantly to science, especially the scientific aspects of agriculture, engineering, dentistry, medicine and veterinary science.

Agreement of the nominee must be obtained by the nominator before submission and included with the nomination.

The winner will be expected to write a review paper of their work for submission to the Society's Journal and Proceedings.

Only electronic submissions will be accepted. Nominations and supporting material must be submitted to the Honorary Secretary at secretary@royalsoc.org.au no later than **30 September 2013**.

The winner will be announced and the Medal presented at the Annual Dinner of the Royal Society of NSW to be held in 2014.

The Warren Prize 2013

The Warren Prize has been established by the Royal Society of NSW to acknowledge Professor William Henry Warren's contribution both to the Society and to the technological disciplines in Australia and internationally. In 1884, Professor Warren established the first engineering faculty in New South Wales at the University of Sydney and was appointed as its Professor. He was President of the Royal Society of New South Wales on two occasions. He had a long career of more than 40 years and during this time was considered to be the most eminent engineer in Australia. When the Institution of Engineers, Australia was established in 1919, Professor Warren was elected as its first President. He established an internationally respected reputation for the Faculty of Engineering at the University of Sydney and published extensively, with many of his papers being published in the *Journal and Proceedings of the Royal Society of New South Wales.*

The aim of the prize is to recognise research of national or international significance by engineers and technologists in their first two decades or so of professional practice. The research must have originated or have been carried out principally in New South Wales. The prize is $500.

Entries are by submission of an original paper written to academic standards. The paper should review the research done and identify its national or international significance. Preference will be given to entries that demonstrate relevance across the spectrum of knowledge – science, art, literature and philosophy – that the Society promotes.

Only electronic submissions will be accepted. Papers may be submitted via e-mail to the Society at this address: editor@royalsoc.org.au. Entrants are referred to "Information for Authors" available from the Society's web-site at URL:
http://www.royalsoc.org.au/publications/author_info.html

Entries for the 2013 award close on **30 September 2013**.

The winner will be announced and the Prize presented at the Annual Dinner of the Royal Society of NSW to be held in 2014.

The Royal Society of New South Wales History and Philosophy of Science Medal 2013

The Royal Society of NSW History and Philosophy of Science Medal was established in 2013 to recognise outstanding achievement in the History and Philosophy of Science. It is anticipated that this prize, like the Society's other awards, will become one of the most prestigious awards offered in Australia in this field.

Persons nominated will have made a significant contribution to the understanding of the history and philosophy of science, with preference being given to the study of ideas, institutions and individuals of significance to the practice of the natural sciences in Australia.

Entries may be made by nomination or direct submission. All entries should be accompanied by a full *curriculum vitae* and include a one-page statement setting out the case for award. In the case of nominations, the agreement of the nominee must be obtained by the nominator before submission and included with the entry.

The winner will be expected to submit an unpublished essay, drawing on recent work, which will be considered for publication in the *Journal and Proceedings of the Royal Society of New South Wales* during the following year.

Only electronic submissions will be accepted. Entries and supporting material should be submitted by email to the Royal Society of New South Wales, marked to the attention of the Honorary Secretary (secretary@royalsoc.org.au), no later than 31 December 2013.

The winner will be announced and the Prize presented at the Annual Dinner of the Society to be held in 2014. The winner will be notified in February 2014.

Royal Society of NSW Scholarships 2013

The Royal Society of NSW Scholarships are funded by the Society to recognise outstanding achievements by early-career individuals working in a science-related field.

Applications for Royal Society of NSW Scholarships are sought from candidates working in a science-related field in New South Wales or the Australian Capital Territory. Up to three Scholarships will be awarded each year. Applicants must be enrolled as research students at a University in NSW or the ACT, and must be Australian citizens or Permanent Residents of Australia.

The award consists of a certificate acknowledging your achievement, a $500 prize and a free one-year of membership of the Society. The winners will be expected to deliver a short presentation of their work at the Monthly Meeting of the Society and to prepare a short paper for the Society's Journal.

For further information and inquiries please contact the Society at info@royalsoc.org.au.

Applicants should email their submission to: secretary@royalsoc.org.au **by 30 September 2013**.

The winners will be invited to make a presentation on their work at the first Society's first meeting in 2014 to be held in Sydney on Wednesday, 5 February. 2014

Archibald Liversidge: Imperial Science under the Southern Cross

Roy MacLeod

Royal Society of New South Wales, in association with Sydney University Press
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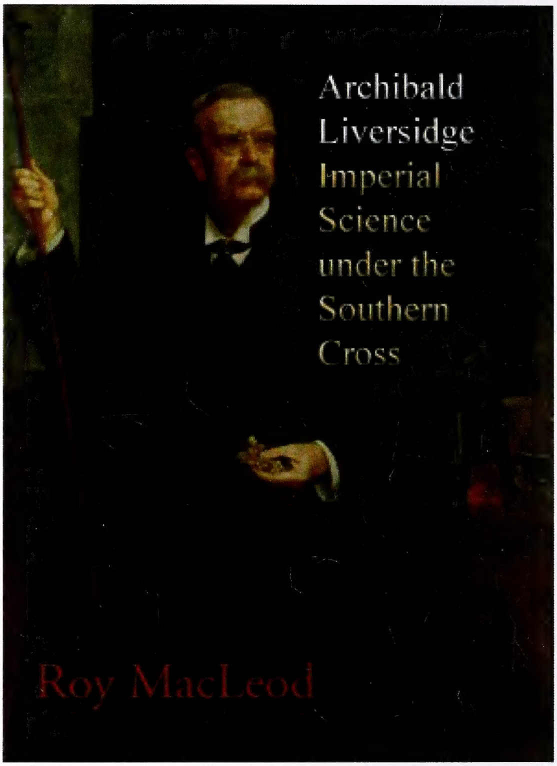

When Archibald Liversidge first arrived at the University of Sydney in 1872 as Reader in Geology and Assistant in the Laboratory, he had about ten students and two rooms in the main building. In 1874, he became Professor of Geology And Mineralogy and by 1879 he had persuaded the University Senate to open a Faculty of Science. He became its first Dean in 1882.

In 1880, he visited Europe as a trustee of the Australian Museum and his report helped to establish the Industrial, Technological and Sanitary Museum which formed the basis of the present Powerhouse Museum's collection. Liversidge also played a major role in establishing the *Australasian Association for the Advancement of Science* which held its first congress in 1888.

This book is essential reading for those interested in the development of science in colonial Australia, particularly the fields of crystallography, mineral chemistry, chemical geology and strategic minerals policy.

To order your copy, please complete the form Liversidge Book Order Form available at: http://royalsoc.org.au/publications/books/McLeod_Liversidge_Order_Form.pdf and return it together with your payment to:

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The Royal Society of New South Wales

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